# SUMMARY OF ANNUAL WAVE POWER FOR TEN DEEP WATER STATIONS ALONG THE CALIFORNIA, OREGON & WASHINGTON COASTS

by

J. W. JOHNSON

J. T. MOORE

F. B. ORRETT

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NATIONAL TECHNICAL INFORMATION SERVICE Springfield, Va. 22151



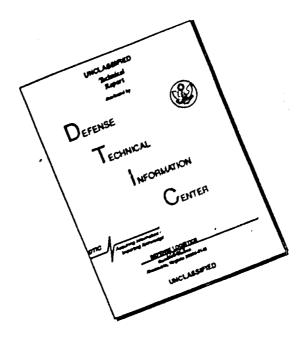
HYDRAULIC ENGINEERING LABORATORY COLLEGE OF ENGINEERING

UNIVERSITY OF CALIFORNIA
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13. ABSTRACT			

The conclusions reached in this report are based on wave statistics for ten locations on the California, Oregon and Washington coasts, compiled in 1960 by the National Marine Consultants for the Corps of Engineers Districts. These deepwater wave statistics were compiled by hindcast procedures using meteorological records and charts from 1956 through 1958. Wave height, direction, and wave period for "sea" and "swell" were averaged monthly and annually. While sandy beaches may change as a result of changing wave conditions, rocky shorelines change very little from wave action over hundreds of years. Seasonal variations of wave power were analyzed on a morthly basis, and are graphically presented as wave power vs. period and power vs. direction.

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### University of California Hydraulic Engineering Laboratory Technical Report HEL-24-9

SUMMARY OF ANNUAL WAVE POWER

FOR

TEN DEEP WATER STATIONS

ALONG THE

CALIFORNIA, OREGON, AND WASHINGTON COASTS

by

J. W. Johnson J. T. Moore

E. B. Orrett

This compilation was completed on research projects on coastal inlets (Contract DACW 72-71-C-005) and nearshore sediments (Contract 72-67-C-0015) with the Coastal Engineering Research Center, Corps of Engineers, U.S. Army.

Berkeley, California

October 1971

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Technical Report HEL-24-9

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71	**	B-74 to B-80	***	11	**	**	**	**	1.42
**	**	B-81 to B-87	"	***	**	**	"	**	1.40
11	**	B-88 to B-95	***	11	**	11	11	11	1.51

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#### INTRODUCTION

The most important factor in shaping a shoreline and cstablishing the characteristics of beaches is the intensity of the wave attack. Rocky shorelines change very little over several hundreds of years as a result of wave action. The sandy portions of a shoreline (beaches), however, may undergo changes in a matter of even a few hours as a result of changing wave conditions. Beaches which are subjected to waves from a variety of directions and of a variety of heights and periods are much more complex in both plan and profile than beaches which are affected by less variable wave conditions. Basic to an appraisal of the characteristics of shore processes in a given locality is adequate information on the wave climate.

Wave statistics for ten locations along the Pacific Coast (California, Oregon, and Washington) were compiled in 1960 by the National Marine Consultants for the Corps of Engineers. These deep water wave statistics were compiled by the hindcast procedure using meteorological records and charts for the years 1956, 1957, and 1958. The statistics compiled were wave height, wave direction, and wave period for both "sea" and "swell" and were presented as monthly and annual averages. The locations of the ten stations are shown in Figs. 1 and 2 and are:

#### California Coast

Station 1  $42.0^{\circ}$  N,  $125.0^{\circ}$  W Station 2  $39.6^{\circ}$  N,  $124.5^{\circ}$  W Station 3  $37.6^{\circ}$  N,  $123.5^{\circ}$  W

 $<sup>^*</sup>$ See references 1 and 2.

 Station 4
 35.5° N, 122.0° W

 Station 5
 34.5° N, 121.0° W

 Station 6
 34.2° N, 120.0° W

 Station 7
 33.5° N, 119.5° W

#### Oregon-Washington Coast

Station 1 44° 40'N, 124° 50'W Station 2 46° 12'N, 124° 30'W Station 3 47° 40'N, 125° 00'W

The meteorological aspects of the wave regime of the Pacific Coast, choice of hindcast years, and hindcast methods are fully explained in the reports (1,2). The statistical summaries are presented both in tabular and rose form.

The data summarized in this report pertain to deep water. To apply the data for any one of the ten stations to a nearby location at or near the shore would require, of course, a consideration of refraction and shoaling effects to arrive at the annual power acting at the inshore socation.

#### WAVE POWER

The calculations for the wave power per foot of wave crest is based on the following relationships:

E = Wave energy per unit width of crest =  $\frac{\gamma H_0^2 L_0}{8}$ 

where:

 $\gamma$  = Unit weight of sea water = 64 lbs/ft

H = Deep water wave height, ft.

 $L_{o}$  = Deep water wave length, ft.

 $= gT^2/2\pi = 5.12 T^2$ 

T = Wave period, sec.

g = acceleration of gravity

In deep water,

Wave power, 
$$P = \frac{E}{2T}$$

or P = 
$$\frac{(64)(5.12) \text{ T}^2 \text{ H}_0^2}{16 \text{ T}}$$

$$P = 20.5 \text{ H}_{0}^{2} T = \text{ft. } 1\text{bs/sec/ft}$$
 (1)

To obtain the total power for a year would involve multiplication of power, P, by the percentage of time that a wave with a given height and period occurs by the number of seconds in a year; that is,

Total power per year =  $P(\% \text{ of time}) (365.33 \times 24 \times 3600^*)$ 

= 
$$P(\% \text{ of time}) (3.17 \times 10^{7*}) = ft lbs/ft/year$$
 (2)

#### WAVE STATISTICS

The annual wave power for the ten deep water stations along the California, Oregon, and Washington coasts were calculated, tabulated, and summarized in graphical form in laboratory reports (3,4). The proceedings involved in this compilation is illustrated as follows for one of the stations.

Table 1 shows the average annual height-period-direction frequency distribution (per cent) of sea and swell for Station 3 which is located in deep water west of San Francisco. This summary is typical of all ten stations along the Pacific Coast (Figs. 1 and 2)(3, 4). For each wave direction shown in Table 1 a tabulation of per cent of

<sup>\*</sup>In the case of Sea the total seconds per year when the category of calm is included is  $3.17 \times 10^7$ . For Swell, where more than one wave train can exist, the total hours (or seconds) per year varies among the ten stations (for example, see footnote, Table 2, for Station 3).

periods of 7,9,... 17 sec. for both sea and swell. Such data are shown in Table 2 for Statio: as derived from Table 1. The wave power in foot pounds per foot of wave crest per year for the various periods and wave heights was then calculated by Eq. 2\*and tabulated. The .otal power for each wave period and direction was calculated, tabulated, and plotted as illustrated for the NNW direction in Fig. 3. This procedure was repeated for all nine or the directions (SSE to NNW) shown in Table 1. Figure 3 clearly illustrates the relative contribution of wave power for various periods of both sea and swell. A summary plot of annual wave power for all nine directions for sea and swell is shown by the bar graph in Fig. 4. Plots similar to Figs. 3 and 4 for all ten Pacific Coast stations are shown in Appendix A.

#### SEASONAL VARIATION OF WAVE POWER

The deep water data for Station 3 (California) was broken down and further analyzed on a monthly basis (5). Wave power was computed in the same manner previously described except for a change in the time constant (seconds per month used instead of seconds per year)\*\*. The calculated results are presented on graphs of wave power vs. period for all months and directions and on bar charts for each month showing power vs. direction. These graphs are presented in Appendix B.

<sup>\*</sup> Seconds per year for Swell was 3.7  $\times$  10 $^{7}$ .

<sup>\*\*</sup> For Sea, seconds per month varies with the days in the month. For Swell, the number of seconds per month depends on the average number of wave trains in existence during the three years of hindcast.

#### REFERENCES

- Wave statistics for seven deep water stations along the California coast, prepared for the U. S. Army Corps of Engineers Districts, Los Angeles and San Francisco. National Marine Consultants, December 1960.
- Wave statistics for three deep water stations along the Oregon-Washington coast, prepared for the U. S. Army Corps of Engineers Districts, Seattle and Portland. National Marine Consultants, May 1961.
- 3. Annual wave power, seven deep water stations along the California coast, by Jon T. Moore and Edwin B. Orrett, Univ. of Calif. Hydraulic Engineering Laboratory Report, Berkeley, August, 1971.
- 4. Annual wave power, three deep water stations along the Oregon-Washington coast, by Jon T. Moore and E. B. Orrett, Univ. of Calif. Mydraulic Engineering Laboratory Report, Berkeley, August, 1971.
- 5. Monthly wave power of sea and swell, Station 3, California Coast, by Jon T. Moore and E. B. Orrett, Univ. of Calif. Hydraulic Engineering Laboratory Report, Berkeley, August, 1971.

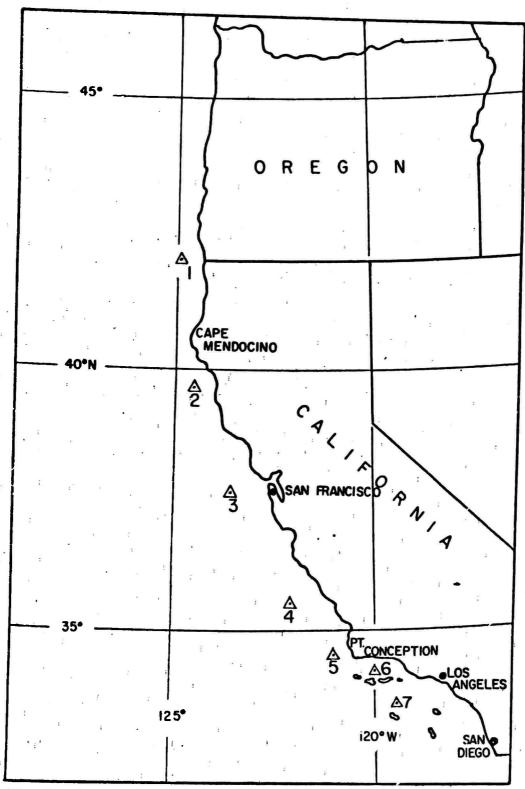


Fig. 1. Locations of hindcast stations along the California coast (From Ref. 1).



Fig. 2. Locations of hindcast stations along the Oregon and Washington coasts (From Ref. 2).

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Fig. 3

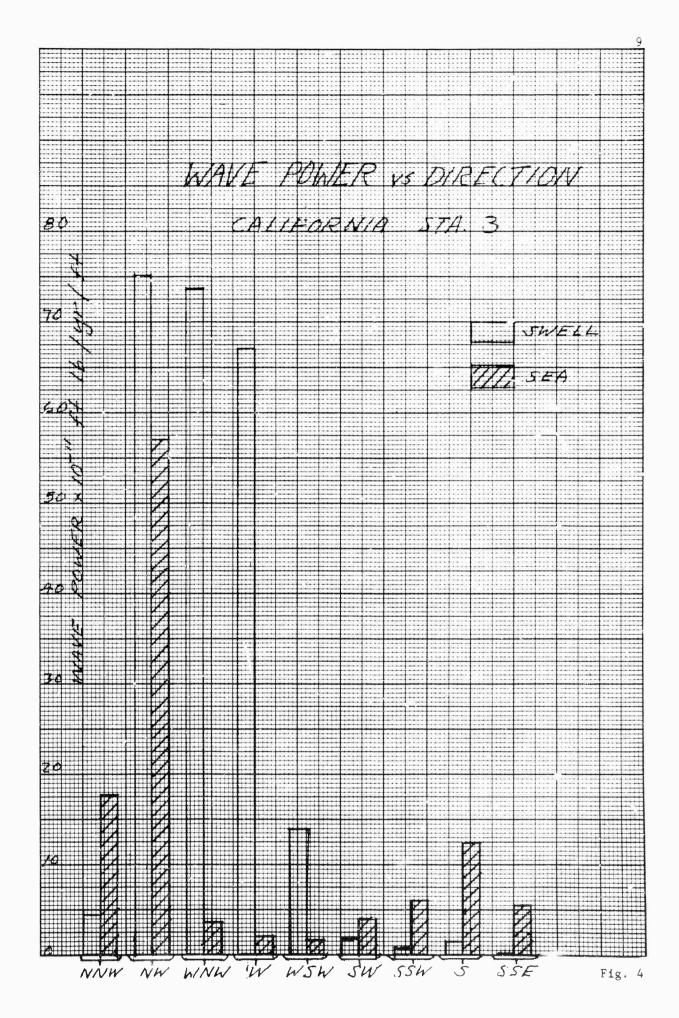


TABLE 1

AVERAGE Annual HEIGHT-PERIOD-DIRECTION FREQUENCY DISTRIBUTION (PERCENT)<sup>1</sup> STATION 3

(1956,1957,1958)

SWELL AVERAGE TOTAL HOURS 17, 150

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TABLE 2. ANNUAL WAVE POWDS: SEA AND SWELL CALLF. STA. 3, NNW

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				0,59 3,96×10 <sup>10</sup>	0,45 3,63×10 <sup>10</sup>	0,45 4.28×10 <sup>10</sup>	0.33 3.71 x1010						2.51 1.3×10 <sup>10</sup>	1.045 .70×10 <sup>11</sup>				
	E time x 10-7			0,59	0,45	0.45	0,33						2.51	1.045				
	3			.16	.13	7.	60.						.79	.33				
	۵		0.45 1.04×10 <sup>10</sup>	5.5071010	3,89×10 <sup>10</sup>	2.54×10 <sup>10</sup>	1,29×10 <sup>10</sup>	1.04×1010				1.84 3.02×10 <sup>10</sup>	7.58 1.74×10 <sup>10</sup>	.1585 4.68×10 <sup>9</sup>				
 	sec/year		0.45	1.82	1.08	0,59	0.26	0,18				<u>.</u>	7.58					
_	E time x10-7		.12	-	.29	91.	6.	.05				88.	2,39	so.				
	Δ.		0,91×10 <sup>10</sup>	2.62×1010	5.72×109	5.16×109	0.074 0.91×10	2.80×109				6.91 2.84x10 <sup>10</sup>	1,64×109					
ж ° с	T sec/year		1.60	3.56	0,63	0.48	0.074	0,185				16.9	. 285					
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 $^{\circ}$  Per Swell, the total number of seconds per year is 10,258,56 × 3600  $_{\odot}$  3.7 × 107.  $^{\circ}$  Per Sea, the total number of seconds per year is 363,33 × 24 × 3600  $_{\odot}$  3,17 × 107.

#### APPENDIX A

GRAPHS OF WAVE POWER FOR

TEN DEEP WATER STALIONS

CALIFORNIA, OREGON AND WASHINGTON COASTS

STATION 1 - CALIFORNIA COAST

Lat. 42.0°N, Long. 125.0°W

WAVE WAVE POWER DIRECTION VS. CALIF STA. ::- 1 .1 90 SWELL 85 11 80 70 60 .ξ. 55 0 50 000 way. 40 35 30 25 70 15 Ю 5 Ν NNW NW WNW WSW SW SSW S SSE W A=1

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NOT INCHES. MARTHUS A. KEUFIEL & ESPER CO.

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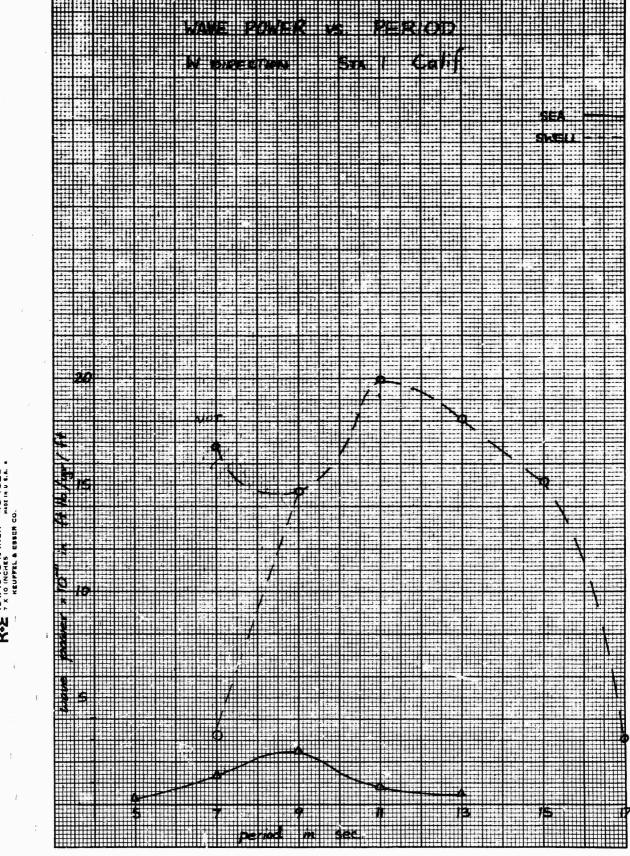
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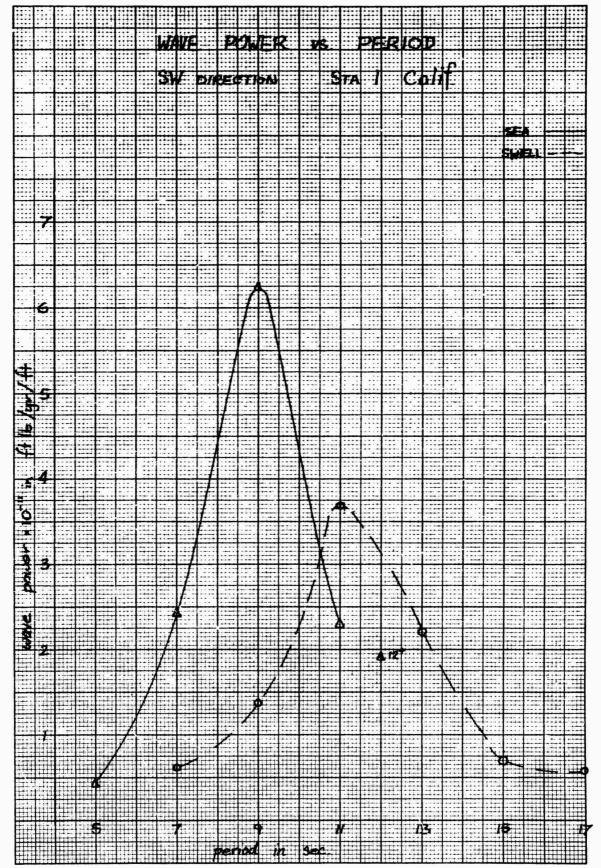


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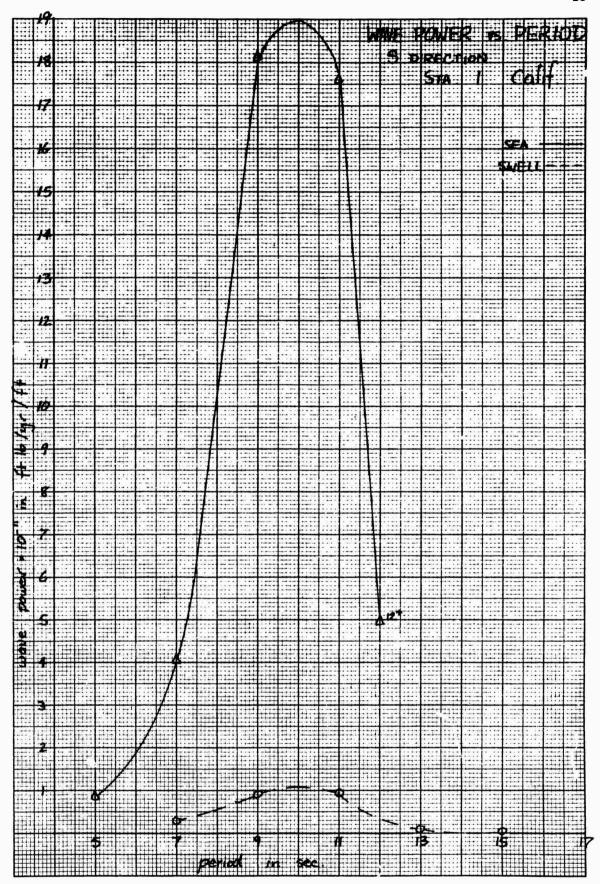


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K-E 10 X 10 TO M INCH 46 1323 KEUFFEL & ESSER CO.

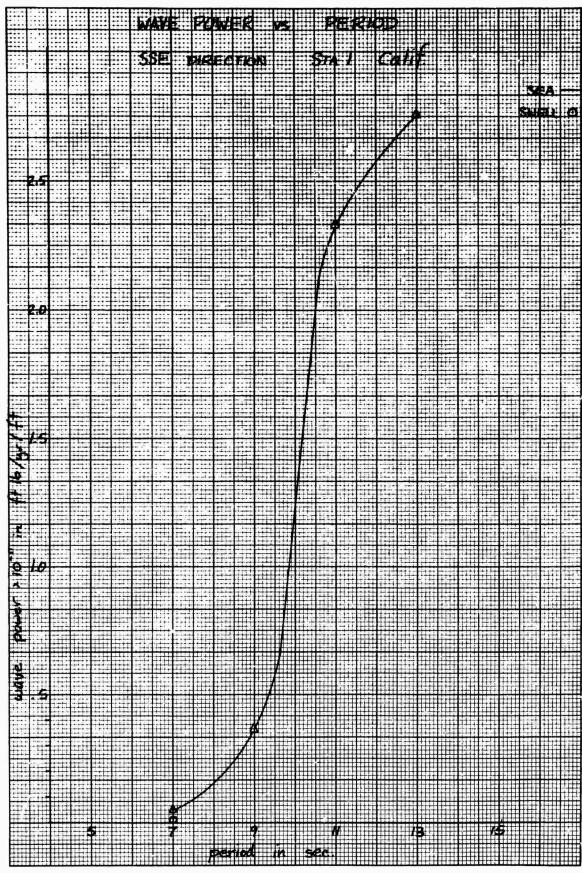


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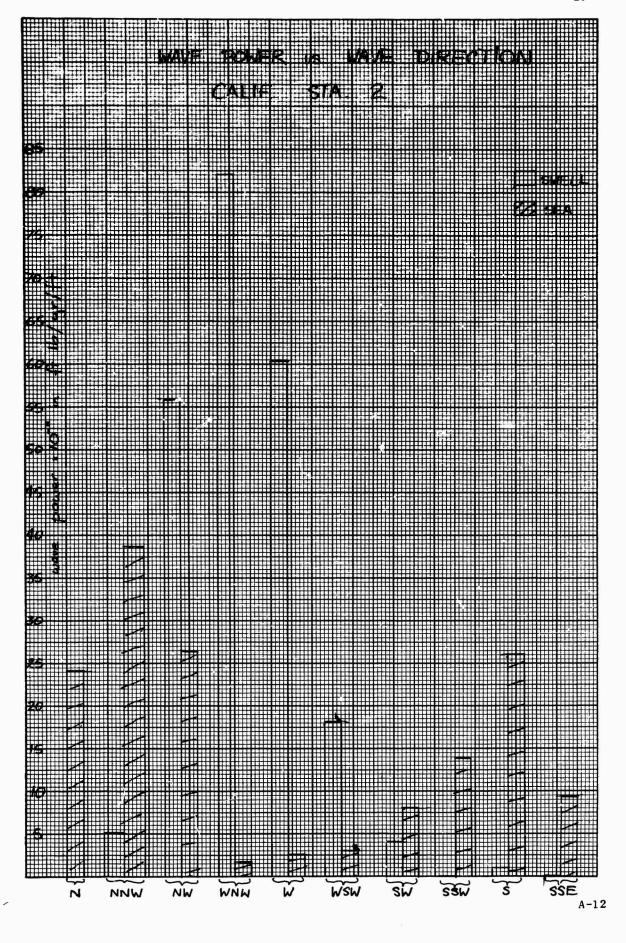
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STATION 2 - CALIFORNIA COAST

Lat. 39.6°N, Long. 124.5°W

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K-M 10 X 10 TO 10 INCH A6 1920

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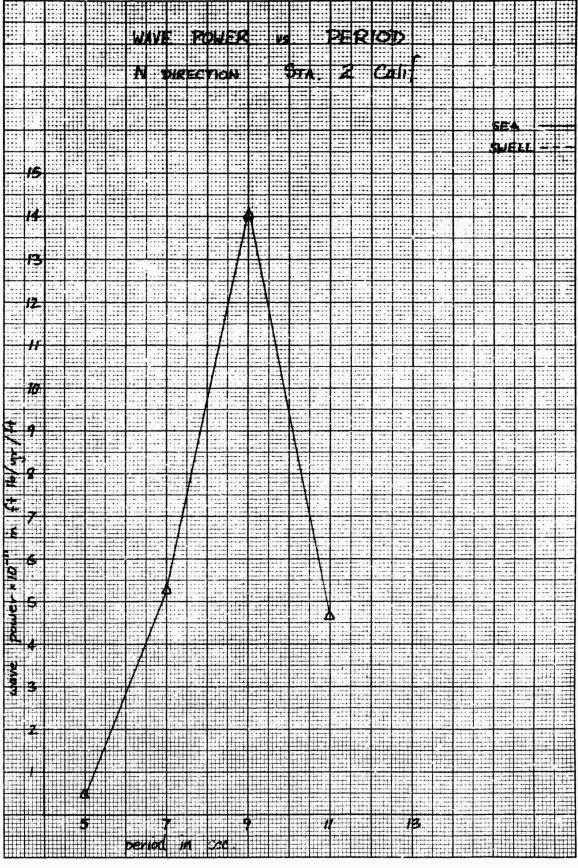
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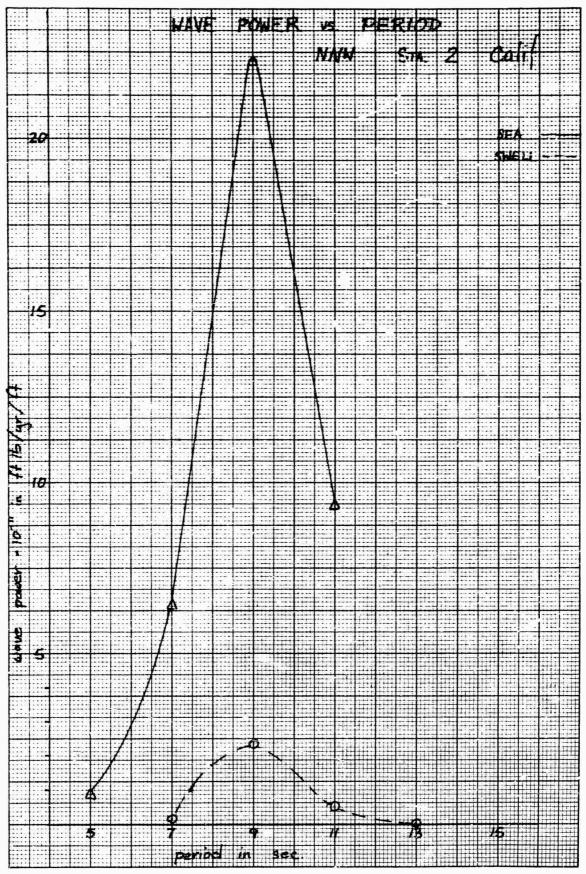
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K-E 10 X 10 TO 1/3 INCH 46 1323

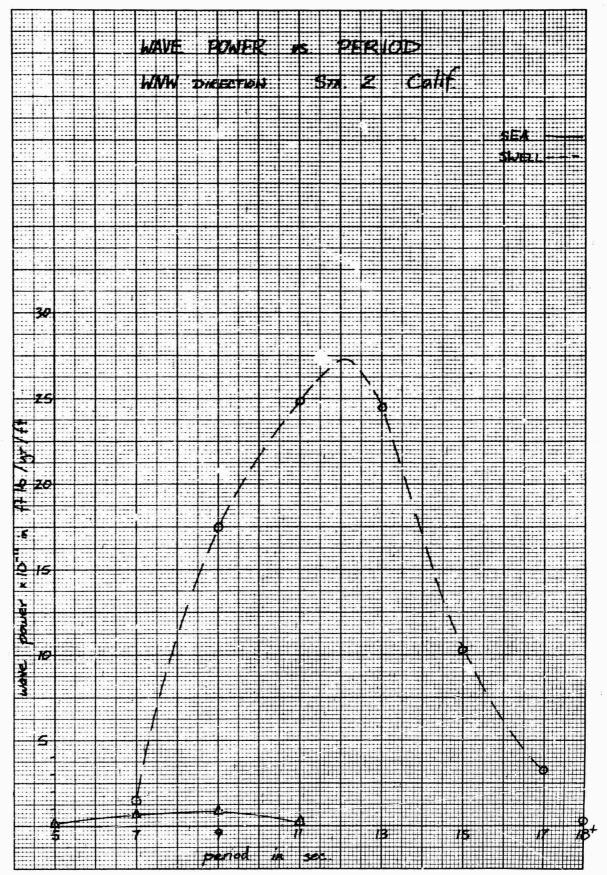


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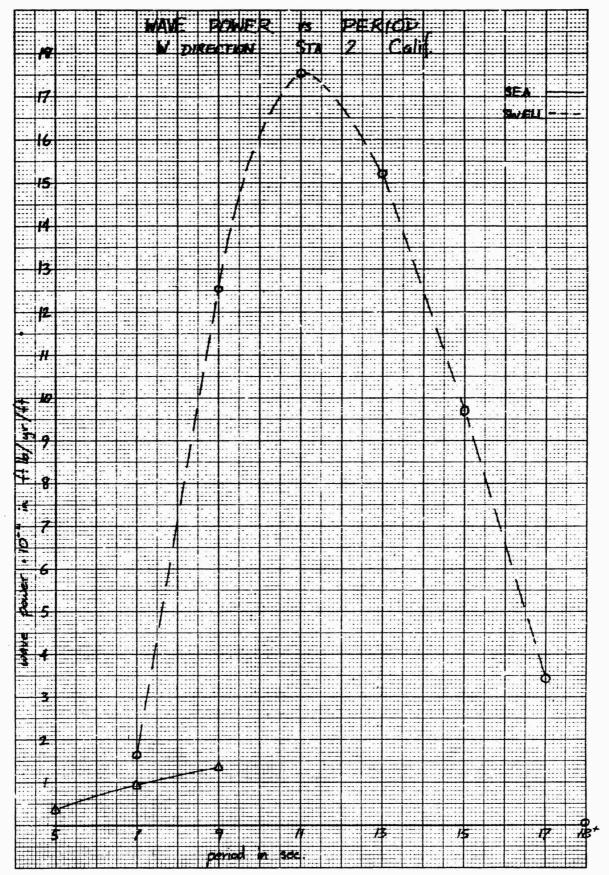
KAE 10 X 10 TO 15 INCH 46 1323

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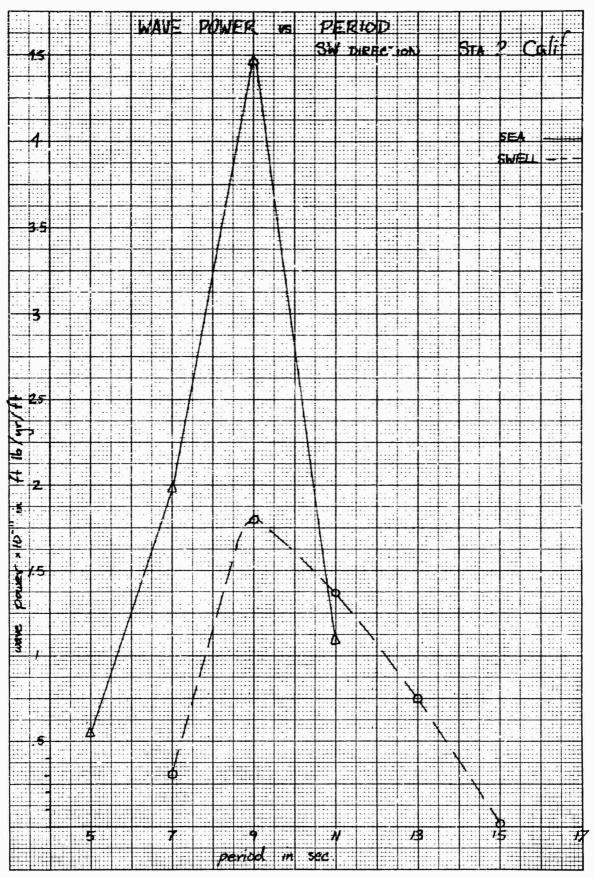
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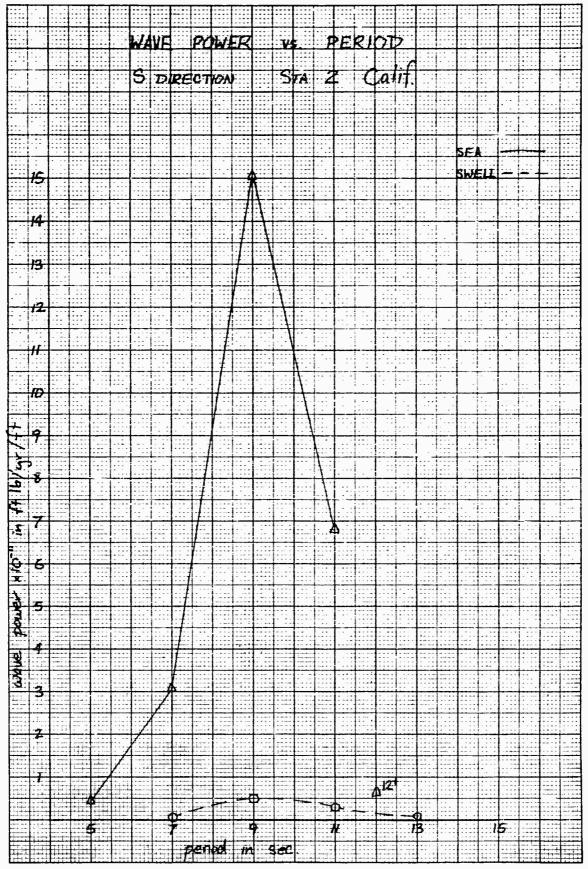
K. 10 x 10 TO 12 INCH 46 1323 REUFFEL 8 ESSER CO



JAVE POWER Calif SSW DIRECTION 12/2 , <u>.</u> pomer . 101 . Seve 

KOE 10 X 10 TO 1/2 INCH 46 1323 KEUFFELT ESGREGO.

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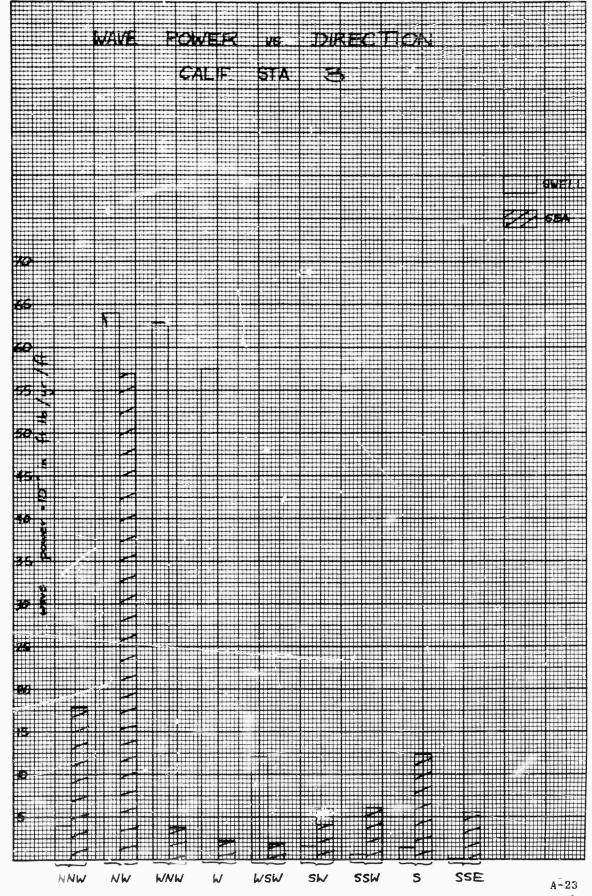
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STATION 3 - CALIFORNIA COAST

Lat. 37.6°N, Long. 123.5°W

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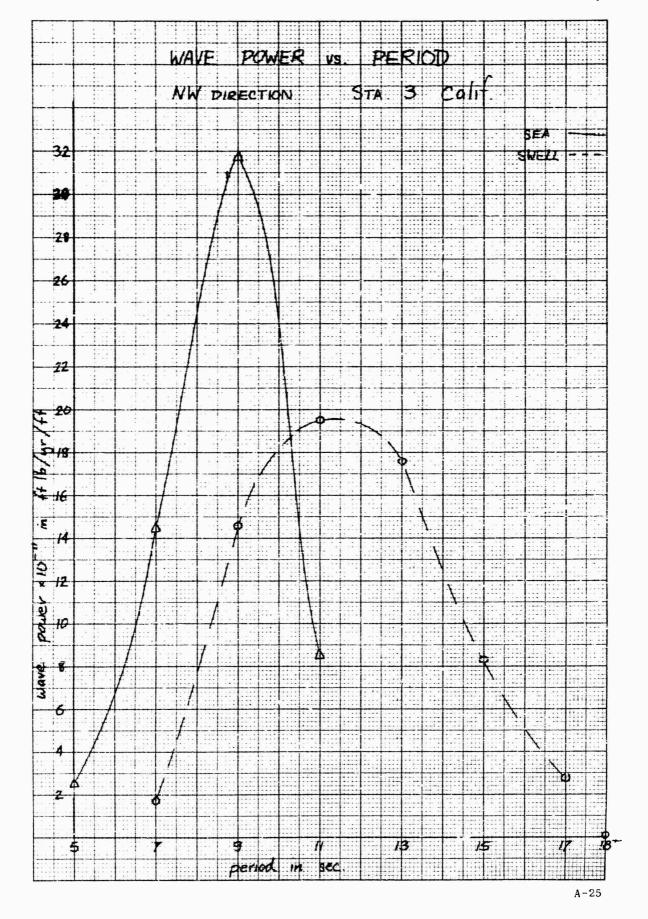
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K-E 10 X 10 TO V INCH 46 1323

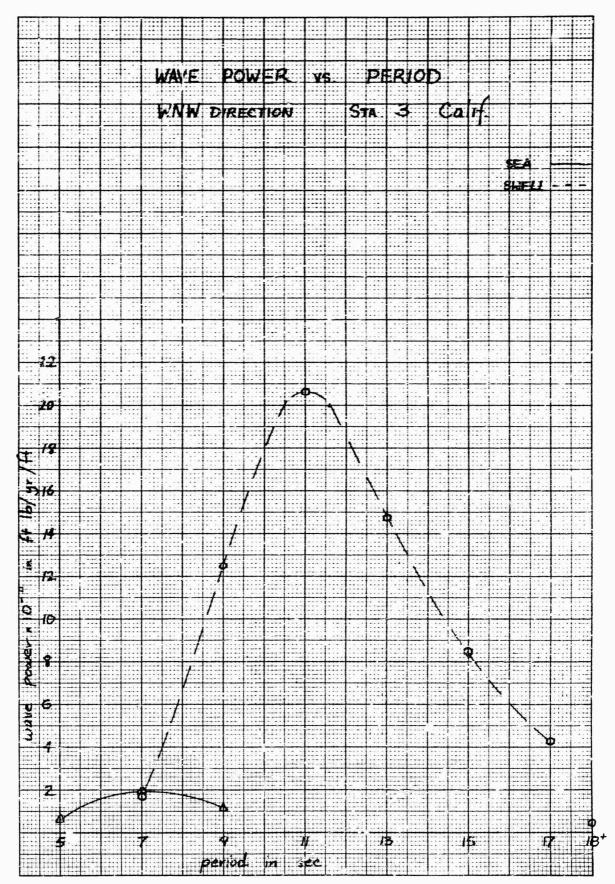
KEUPPEL & ESSEN CO.

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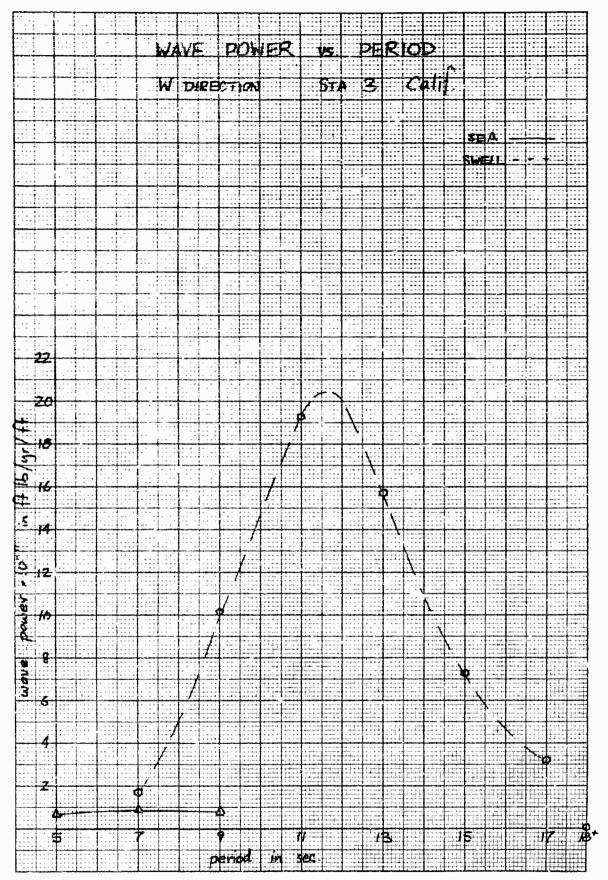


Maria 10 x 10 TO 19 INCH 46 1323

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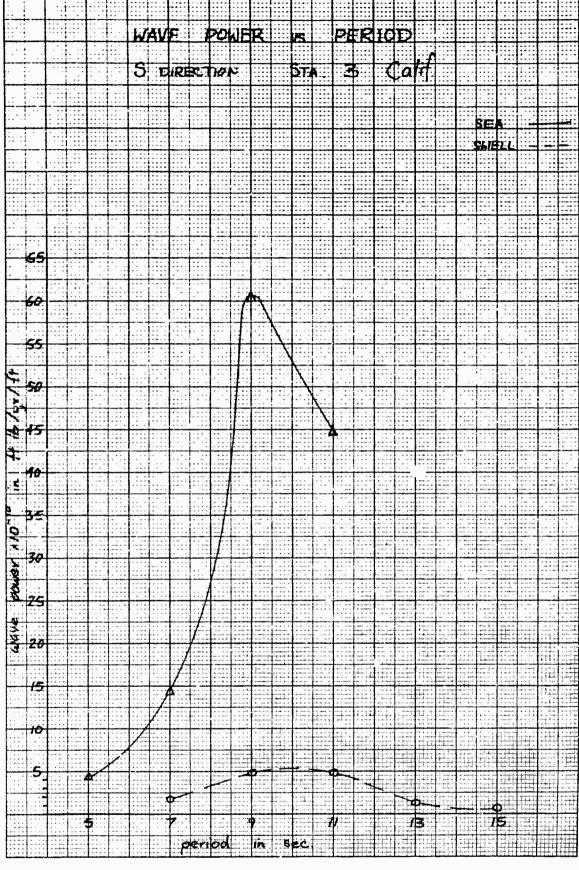
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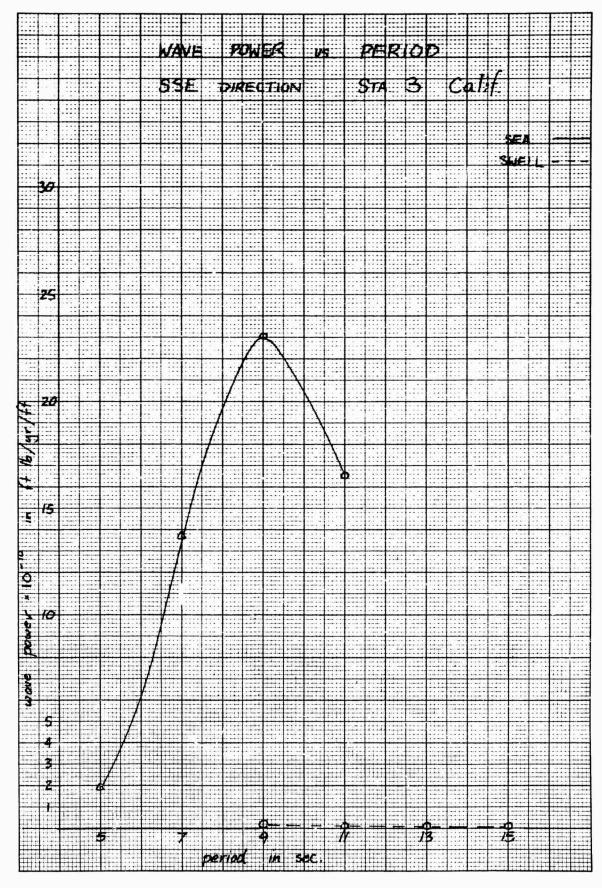
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10 X 10 TO V2 INCH 46 1323 7 X 10 INCHES V10 IN B U LA. • KEUPPEL 3 E9SER CO. Ž Ž



Kom to X 10 TO Vy INCH 46 1323

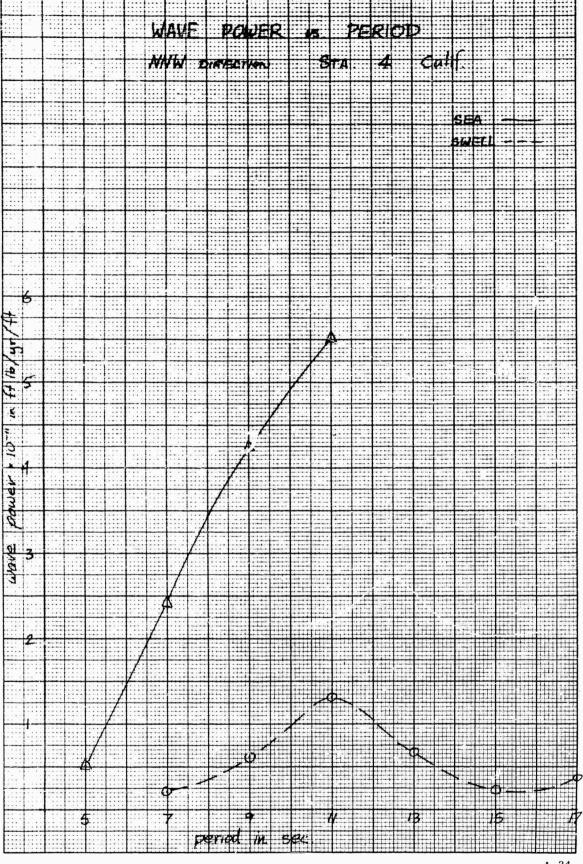


STATION 4 - CALIFORNIA COAST

Lat. 35.5°N, Long. 122.0°W

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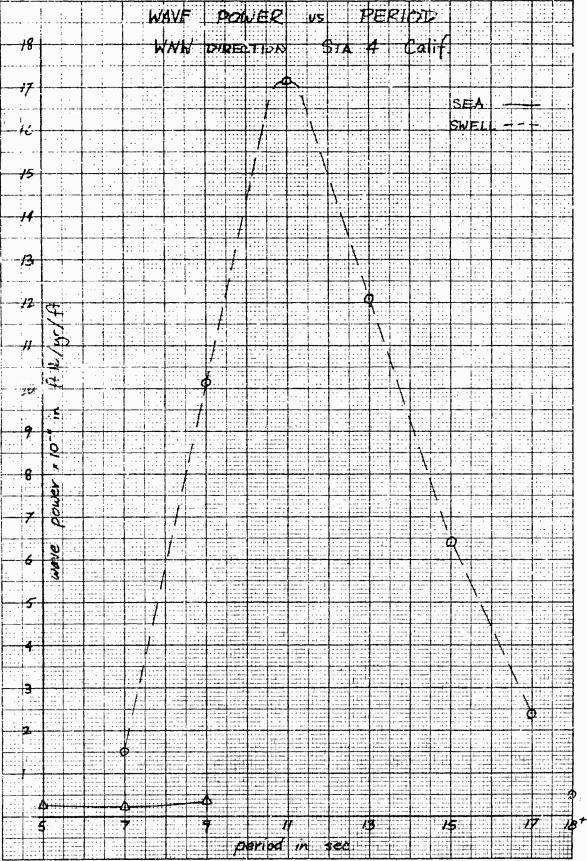
K+T 10 X 10 TO V2 INCH 46 1920 MARTIN U.S.A. MARTIN U.S.A. WEBER CO.



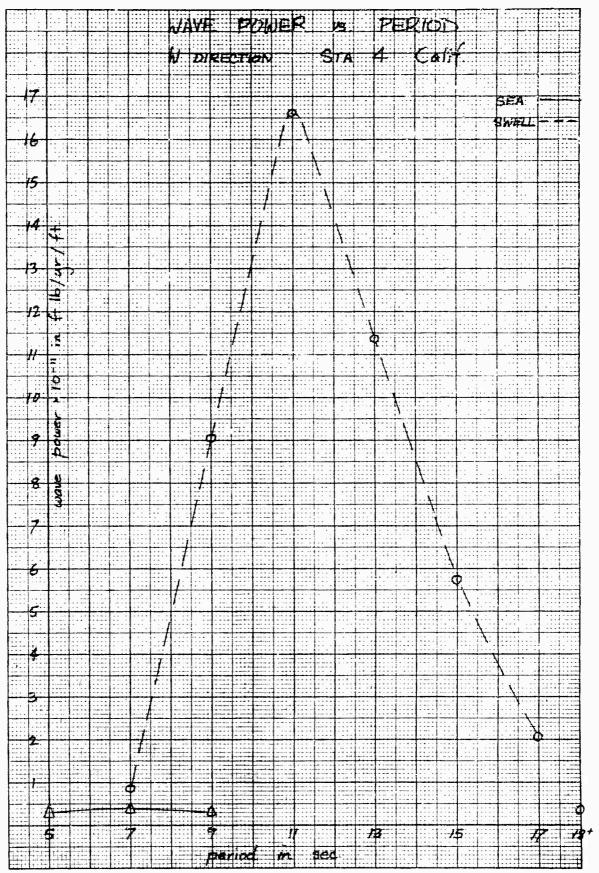
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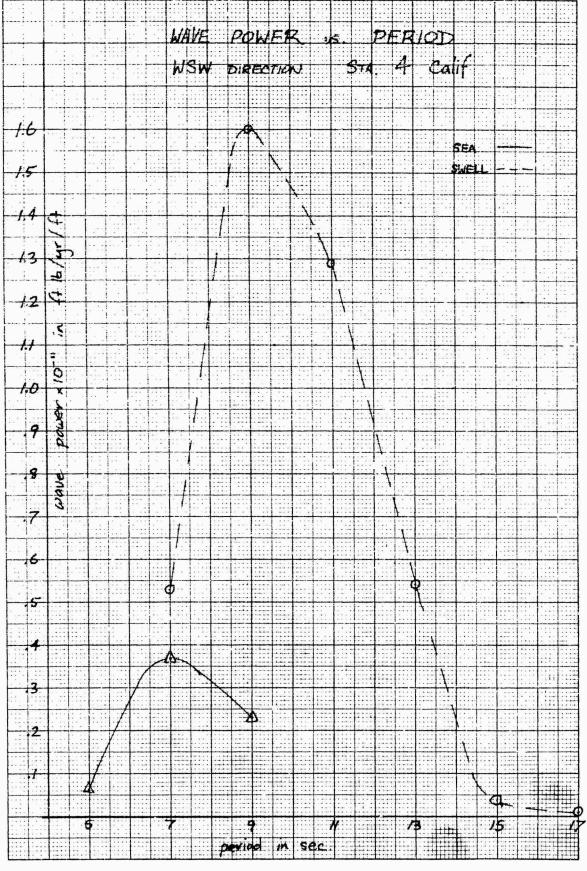
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KOM 10 X 10 TO 1/2 INCH 46 1323



# 10 X 10 TO 10 10 INCH 46 1323





KON 10 X 10 TO 12 INCH 46 1323

KLUFFEL A 45300 CO.

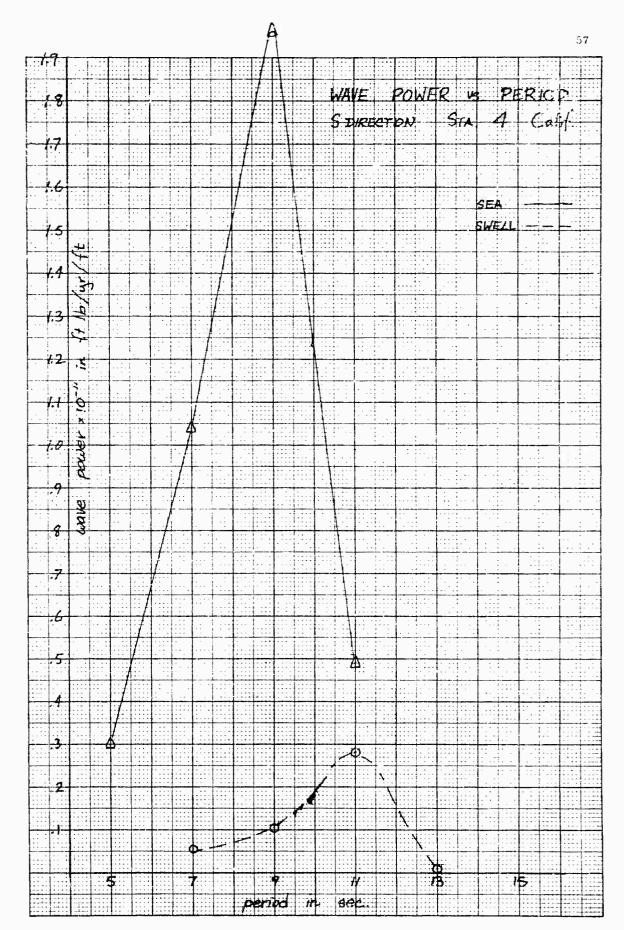
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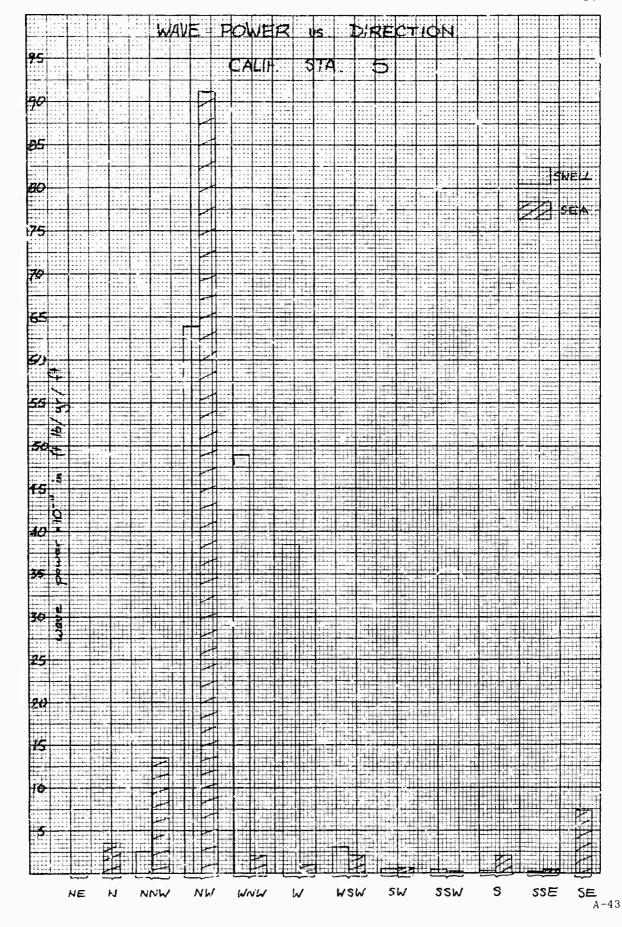


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M 10 X 10 TO 1/2 INCH 46 1323

STATION 5 - CALIFORNIA COAST

Lat. 34.5°N, Long. 121.0°W

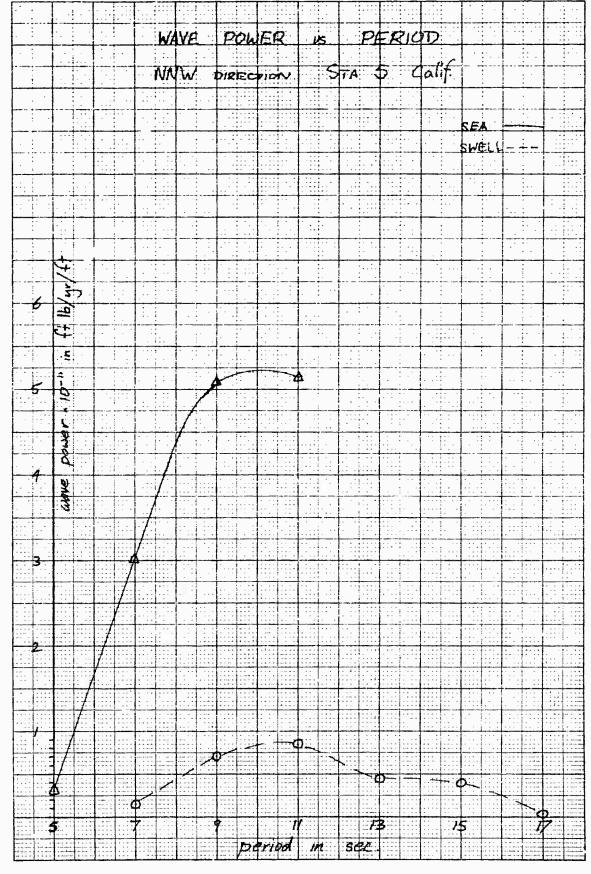


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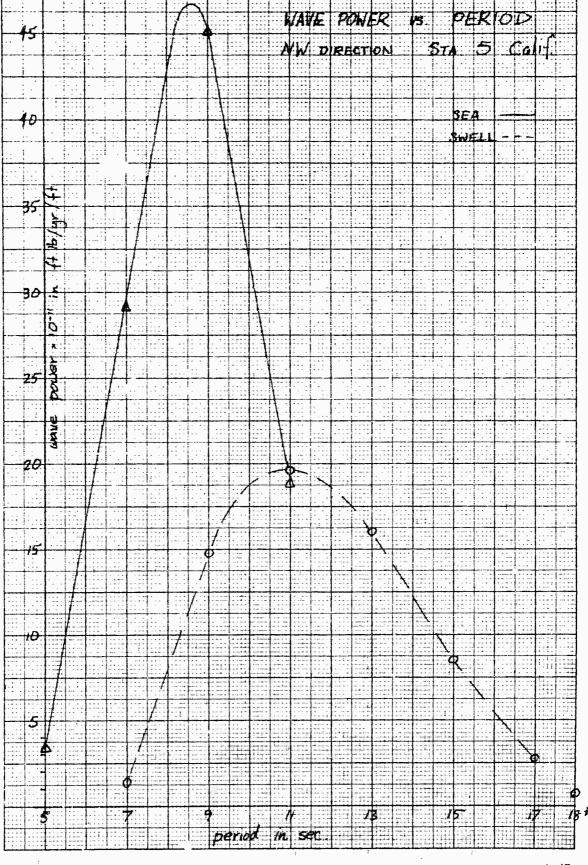
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10 / 10 / 10 TO 12 INCH 46 1323

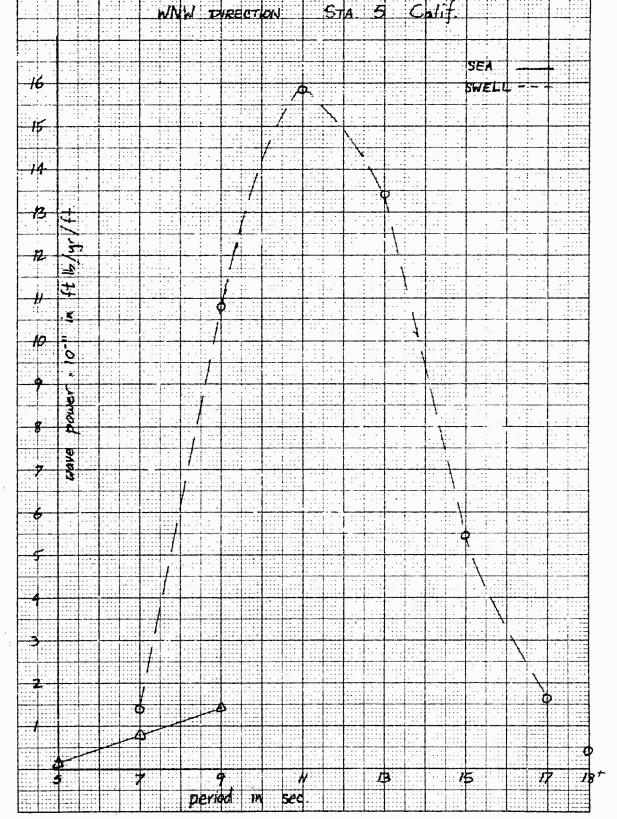


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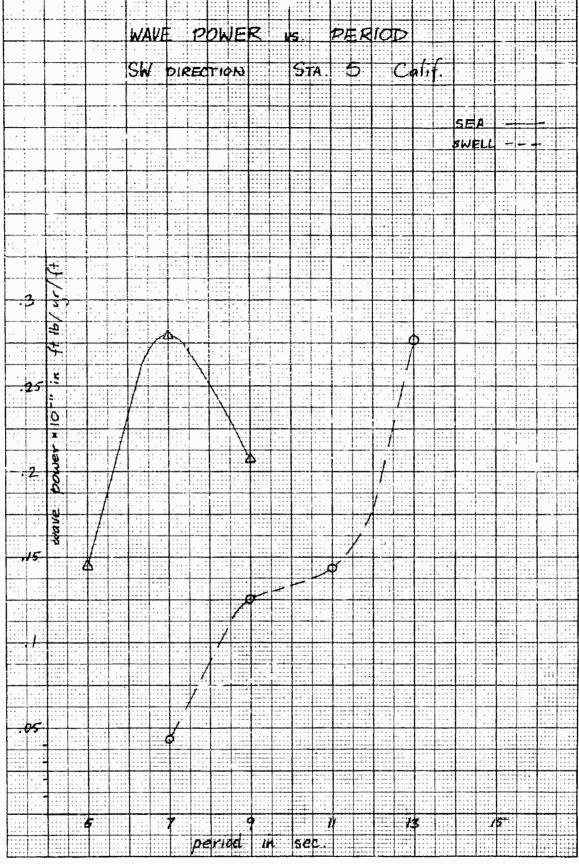
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A-48

MAVE POWER PERIOD VS. Colif W DIRECTION 1...: : 1. 17.3 : SEA SWELL ļ::. 1 ; · : : 3 a 12 1. 1::: ..:Ī. Æ `:. <u>x</u> 10 pawer 5 3 2 Φ: 1 75 17 period 771 Sec

PERIOD WAVE PUMER יפע --::: STA 5 ... Coli W\$W DIRECTION SEA . ..... -.: . : EWELI 1 : ::: :.: . - . . . . . . ... :::: .; :::: ::::: - -.::: : . • : : . . . 12 : 0 -:.: : . .; 1.-----1: .1:. ; 10 101 .: \* DOWN 1 .; ,8 wave - : 1 1.6 . 1.: 1 - [::: .::|.:. 1 :: 3 `... 2 5 13 15 7) period in sed:

(40) 10 X 10 TO 11 INCH 46 1323 KEUFFEL & 137 FLC



KOM 10 X 10 TO 15 INCH 46 1323

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VS. SDIRECTION STA Calif. : [1 SWELL (+1) 14/41 5 0 A Save 3 13 15

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10 X 10 TO <sup>1</sup>2 INCH Z 1 x 30 NOTE: KEUFFEL & ESSAR CO. Ž

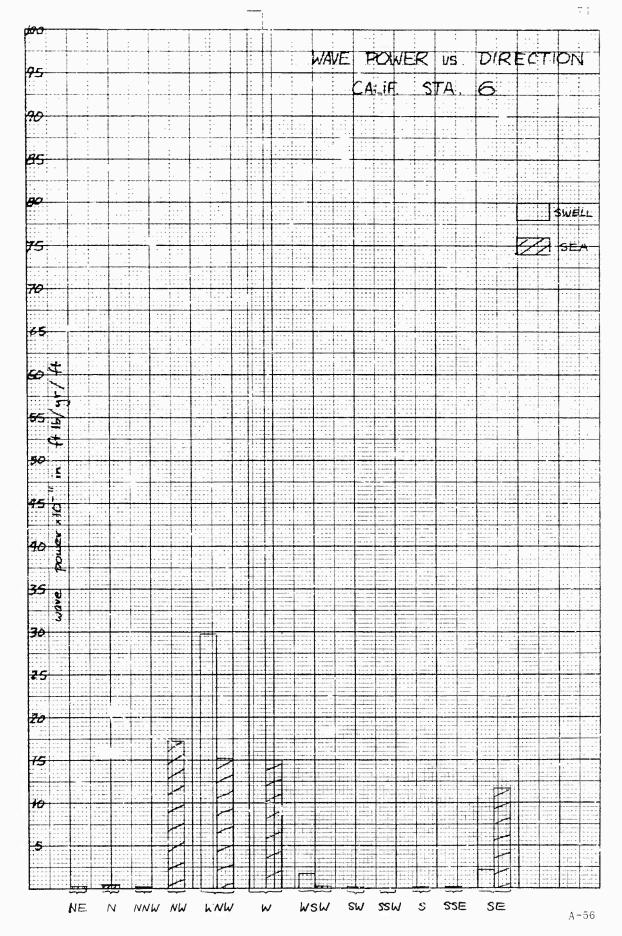
A-54

WAVE PER IOD ROWER STA DIRECTION BEA SWELL 40 <del>3,5</del> 14 16/4 3.0 11 25 (O<sup>-</sup>" Dower x 20 mane 1.5 Ш 5 period in Set.

10 X 10 TO 12 INCH 46 1323

STATION 6 - CALIFORNIA COAST

Lat. 34.2°N, Long. 120.0°W



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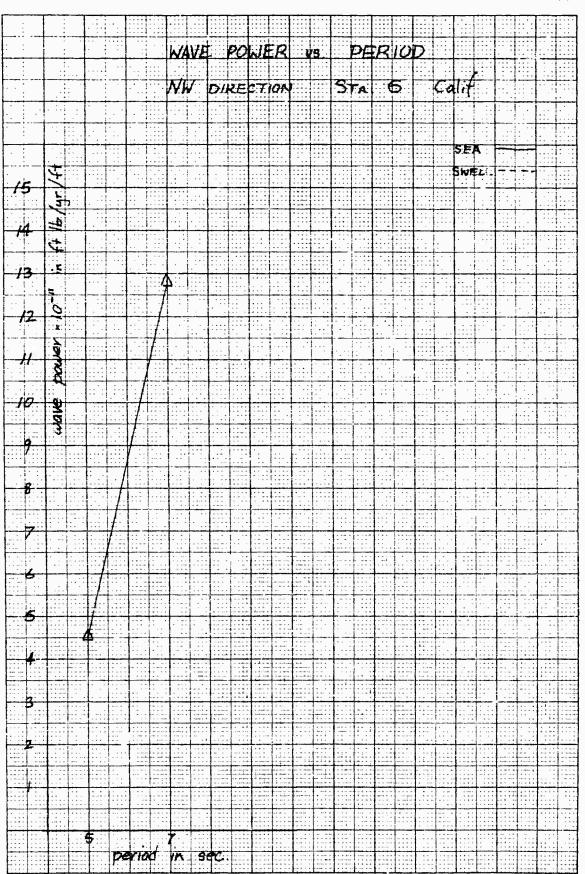
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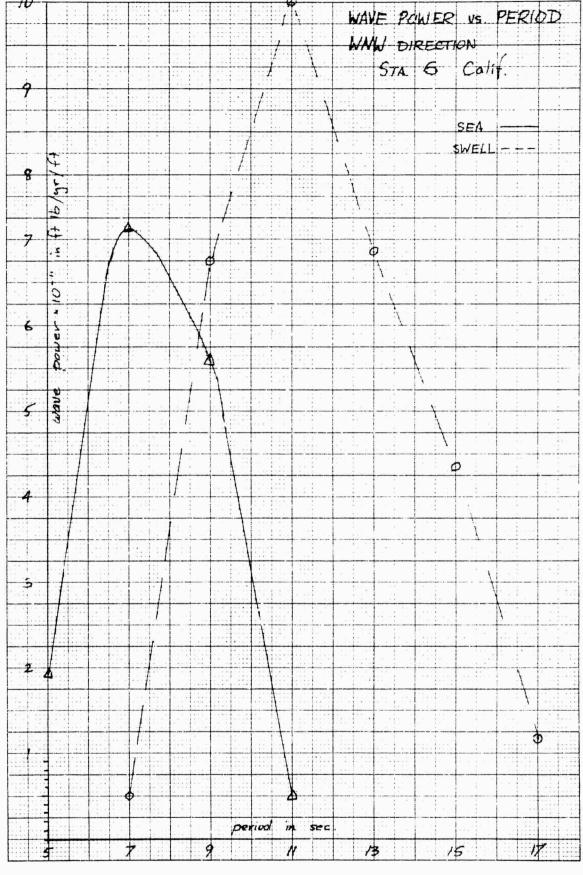
Ko 10 x 10 TO 12 INCH 46 1323 KEUFFEL ESSER CO.

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KOE 13 X 10 TO 12 INCH 46 1323 ALTONOMEN ALTONOMA REPETLA FESTINA FEST





: V3 PERIOD WAVE POWER 46 :-\$TA V DIRECTION 5 Coli · 11.: : :-SEA BHE L . . # Ħ. 5 30 119/0 \$ : [: i . ٠**٤** <del>25</del> 9 + pawer . 20 wave 15 # 10 **/**5 17 /3 period in sec.

WAVE POWER PERIOD US. Calif. WSW DIRECTION Ġ STA -:: SEA . 8 -: Ţ -0 4 - ₹ 2 0 ĸ Jamad <u>: ··</u>. - - -1 wave .3 · : : : :- 1-: . !. \$ 11 /3 15 period 300

10 x 10 TO 12 INCH 46 1323 STUFFEL A C CCCC

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:-<u>.</u> PERIOD V5 . ; . Calif STA 6 DIRECTION SEA SWELL ....: 3 10 H : క్ 0 A. Downer period in

HALL TOXIOTO 12 INCH 46 1323

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PERIOD WAVE POWER VS. DIRECTION SEA Suell 11. / 16, /91 H pomer . 10-" ware 3 ПЩП ... period in sec.

KAE 10 x 10 TO 12 INCH 46 1323 REUFFRE & PERFECT PRINCE NO. STATION 7 - CALIFORNIA COAST

Lat. 33.5°N, Long. 119.5°W

WAVE POWER DRICTION VS. SIA. CALIF SEA . . . . . : : . SWELL 90 80 70 \$ 60 //! S 50 Fame Mare Tota! 30 20 10 NE NNE MY NW WSW **5**W SSW S SSE W SE WWW A-67

TO X TO TO V2 INCH 46 1328

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. IS. WAVE POWER PERIOD . : Calif STA : DIRECTION -.-: . . : : ... ; -----SEA . . . : . : : ! : : : : SWELL . : .:. . : : ÷ ; ; ..: : : : : : : ; :. : • : ٠. : ÷. . : - : ; : <del>|---</del> 0 ... ----1 1. : 1:: 1.... : . . :-0 · · · · · · ..... .::: : . :. . . . . . . ---: ; . . . . DOWEY . ! :.. 20 : -1 1 1 1 . . . . . . Wave : !.:: :1 · i.. :::|: 1.5 10 5 SEC. period m

RM 10 X 10 TO 12 INCH 46 1323

Colif N DIRECTION STA SEA .:|:: 7 4 4 . 4 11-01 × 10-11 2010 50

10 X 10 TO 12 INCH 46 1323 Ž M

. : | - : -PERIOD WAVE POWER VS. ::: . !:: DIRECTION STA Coli WWW ٠. . ---SWELL : . 1.1 - 4 Dower = 10-11 ·: ·. · 1 ! . : ` · : ! wave : 10 - 75 - 1 -.25 m period 1 sec

MART TO X 10 TO TO TO INCH 46 1323

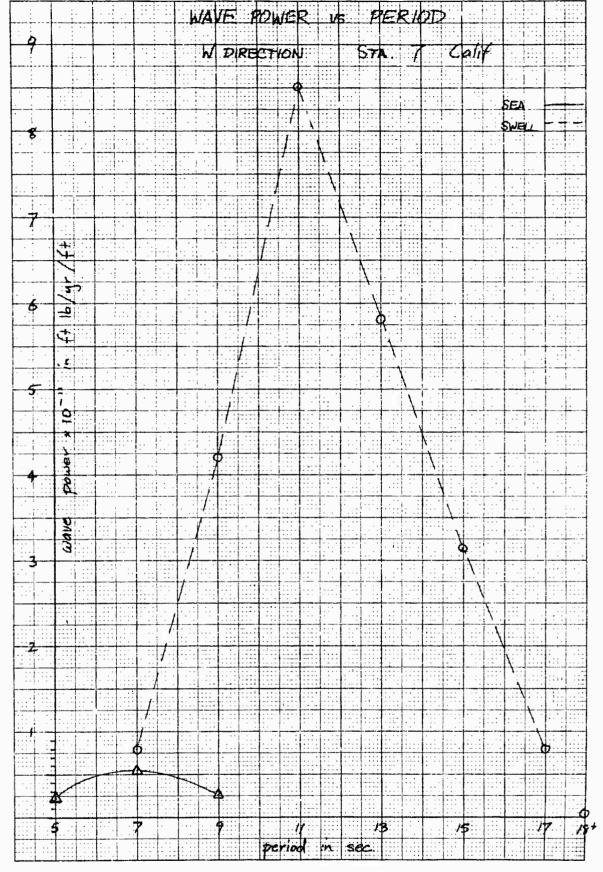
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WAVE POWER IS PERIOT STA DIRECTION SEA 17/26 40 19 35 - **E** 10-01 × 30 pomer 20 15 1::: 10 13 period 'n SEC. 

| 46 | 13 X 10 TO 12 INCH | 46 1323 | 13 X 10 PECA | 12 PECA | 12 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13 PECA | 13

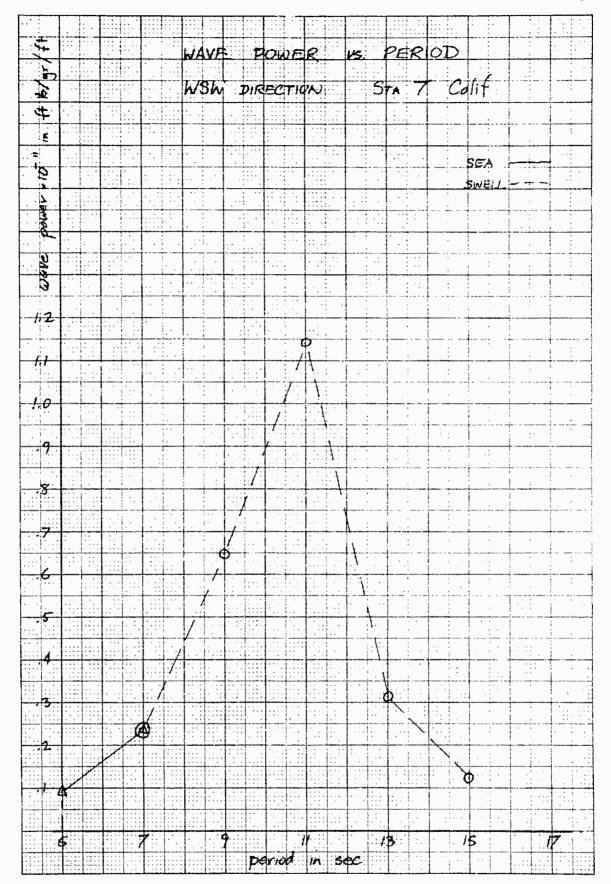
WAVE POWER Vs. PERIOD WNW DIRECTION STA 7 calif 1.1:::: -4:5 20 ::i::: : SEA t) / fai F = FSWELL 1.111 抽 .... 7 T 1 ::: ٤. :::: :: | :::: :::!::: 15 0 .13 . . \* . S. S. i::| :: U . : 500 -:-|--..... 10 1 ::: ---1 4 3 9 2 : # 13 15 18+ pened in sec

10 X 10 TO 12 INCH 46 1323 7 X 10 INCHES 0X 1 IN 0 E.M. KEUFFEL 0 ESSEN CO.



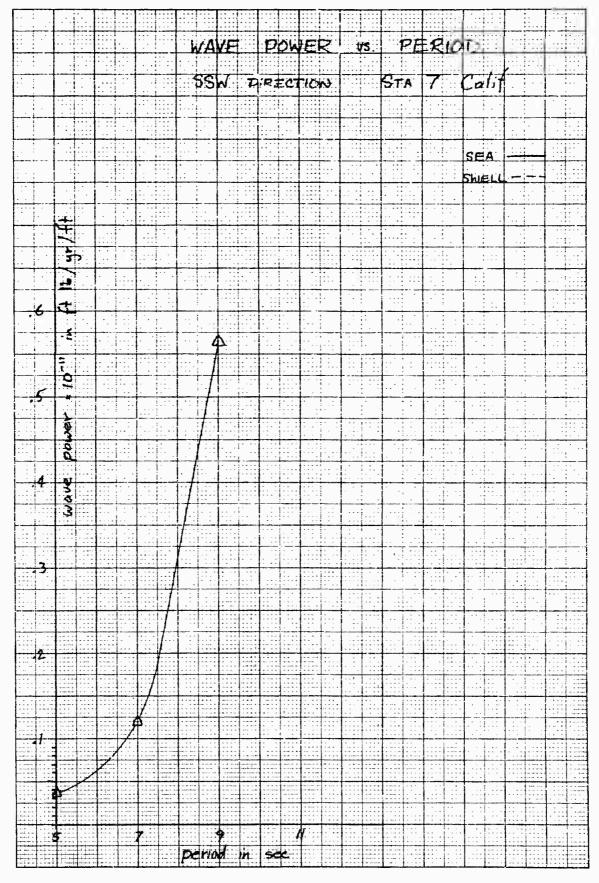
M 10 X 10 TO WINCH 46 1323

19 X 10 TO 10 10 CH 46 1323



F. 1. PERIOD + WAVE DOWER • • • SW DIRECTION STA Cali 4 1 4 SWELL ... 0 Domer - : : : : ----.35 7,000 .3 25 ... 1.5 H period

MAKE TO VIOTO 12 INCH 46 1323
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VAVE POWER VS DIRECTION SEA (m)/ ff .18 Val . . 11-01 -Dower Ŝ - --ir. 13 15 jh. ---teriod

KON 10 X 10 TO 12 INCH 46 1323

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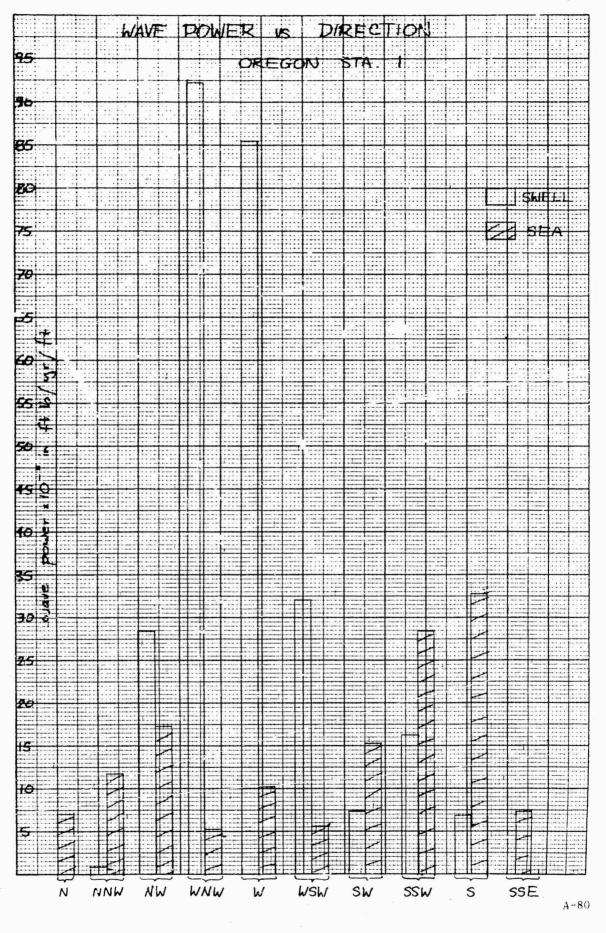
.... PERID VS WAVE POWER 7 Calif DIRECTION :-::-. SEA **EVELL** 1-1-1-+ ...i..: 3 # ::"1:: -6 0 × benesi in little 1.1. ...! WAY :: | -3 4.: 2 :5 period 102 Sec

KOE 10 X 10 TO 12 INCH 46 1323

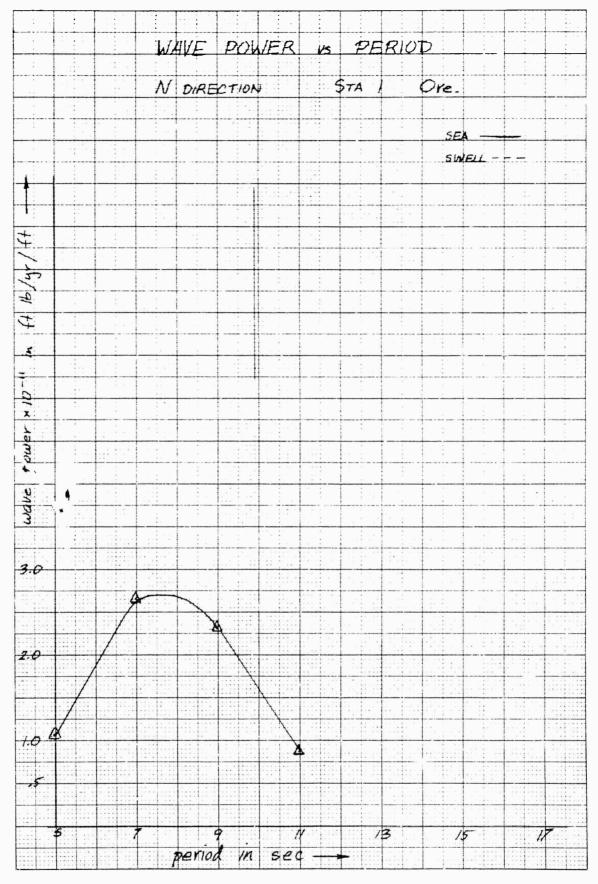
STATION 1 - OREGON COAST

Lat. 44° 40'N, Long. 124° 50'W

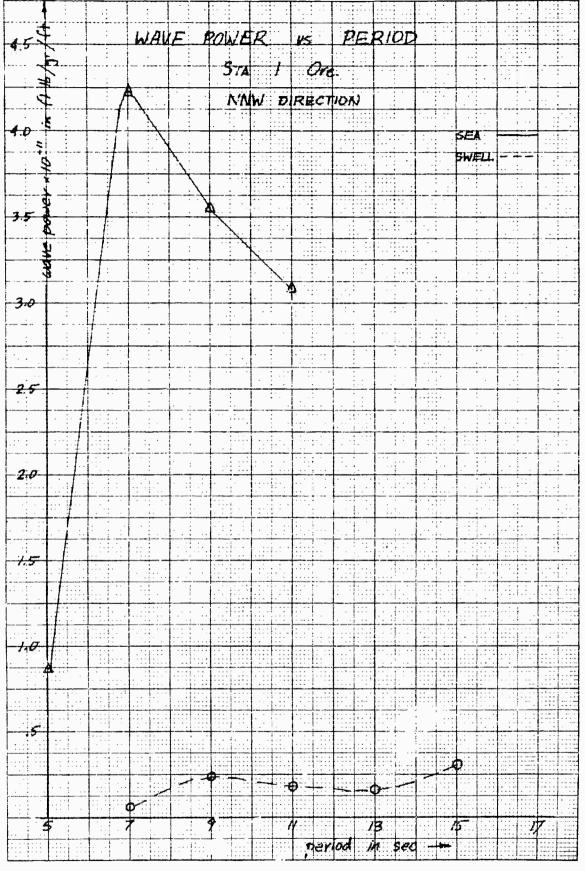
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TOWN TO TO 19 INCH 46 1928



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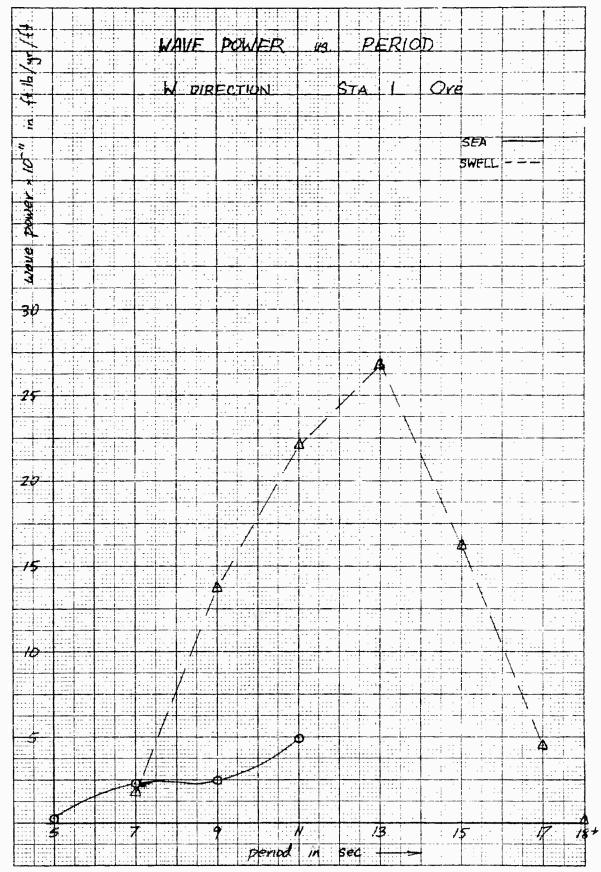


### 10 X 10 TO 12 INCH 46 1323

MACH TO TO THE 46 1323

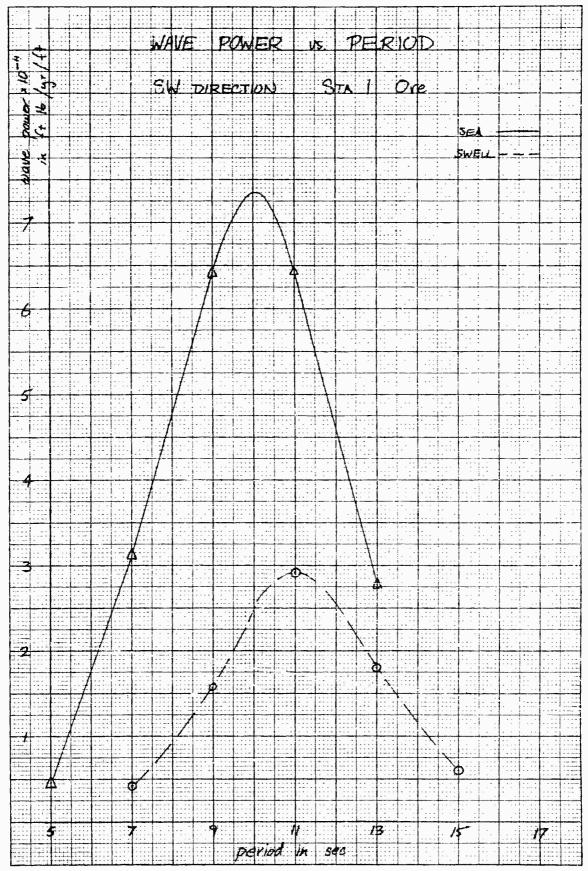
10-" in ft 16/4-/ft WAVE POWER PERIOD WAW STA Ore DIRECTION .... .1-1 SEA 1.1. Ï SWELL :  $\mathbb{H}$ wave . ] : - [. <del>30</del> - ::: 1 : . . ... : : : 25 - : : 20 .1ŧ. -111: 15 10 18+ 7 15: 11 /3 ₹ period m Sec

Me 19 X 10 TO 19 INCH 46 1323



i. li.: WAVE POWER I/S PHRIOD . . . . : WSW STA Ore DIRECTION : ---: SEA ĸ. 41 - Of a samod : [ . :. : ! :: ; tooke :-. : [ : i H-! ID Ø -------: 7 φ 5 ::: 3 1. 1 Φ 4 /3 7 15 11 in period Sec

KAE TO X 10 TO 1/2 INCH 46 1323
KAE TO TO INCHE UND IN US A . REUFFEL & ENERR CO.



PARIOD WAVE SSW DIRECTION E 2 4 ·Ē Fower + 10 12 Cave 8

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SWELL <u>.</u>0 .... 13 : 1 2 -12 . 10 ------

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A-89

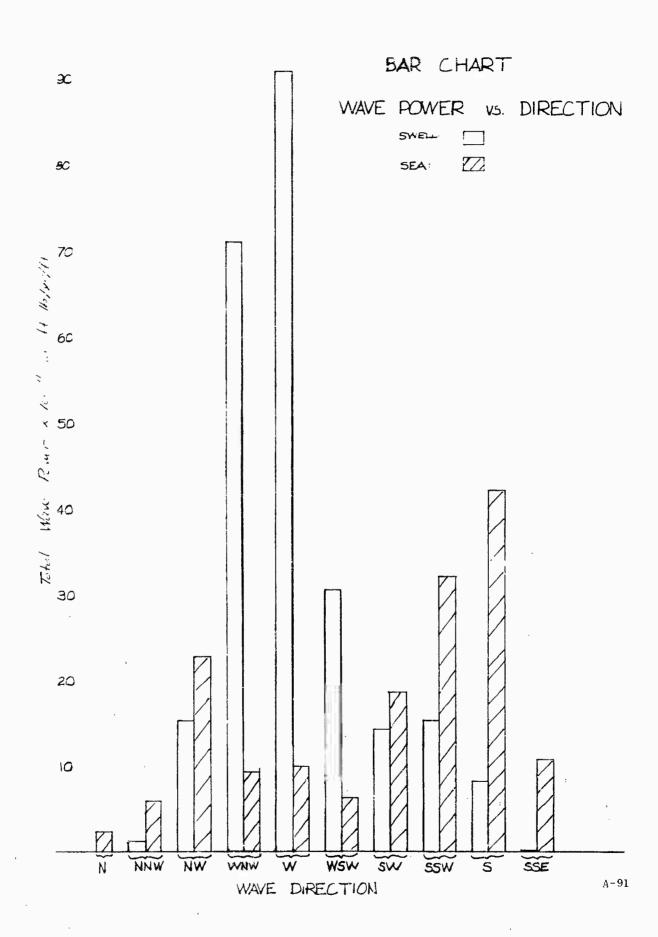
15

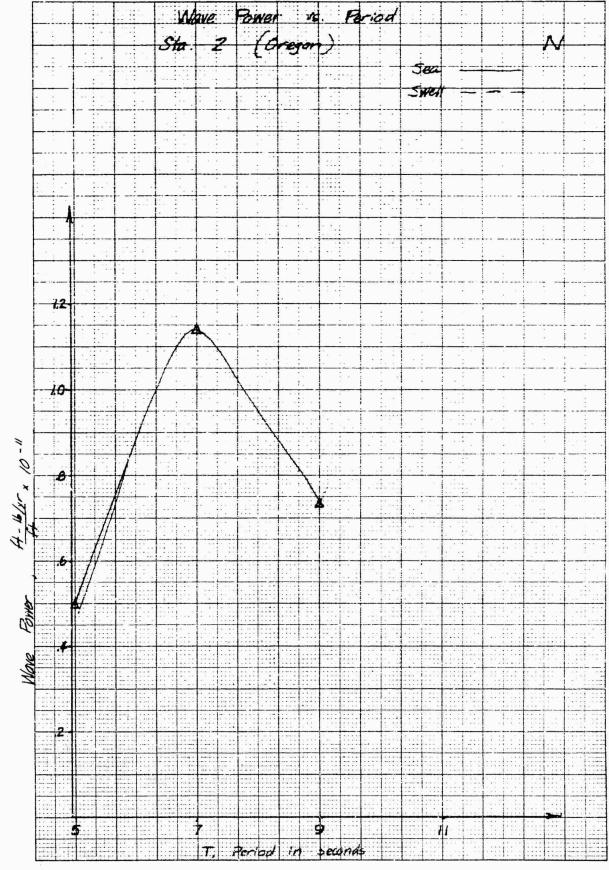
/3

sec

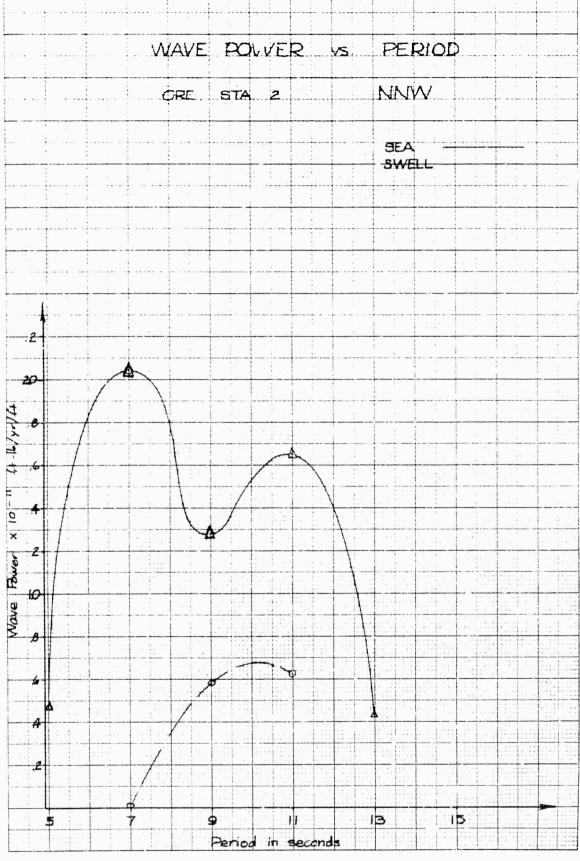
STATION 2 - COLUMBIA RIVER MOUTH

Lat. 46° 12'N, Long. 124° 30'W

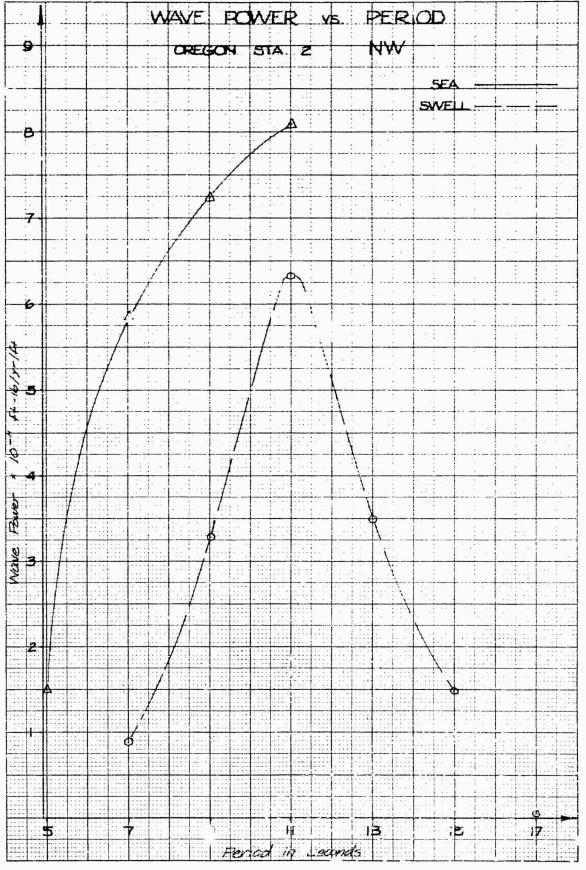


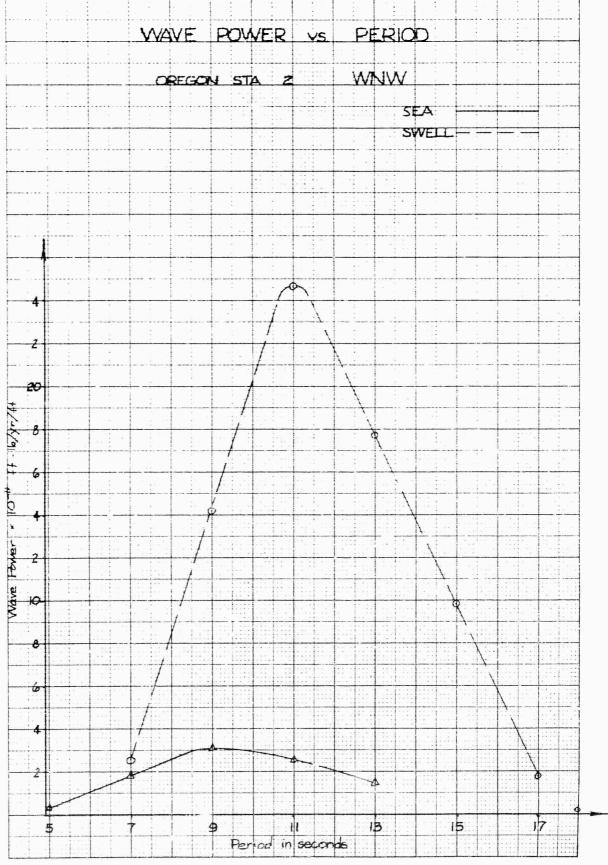


KALL ON TO TO THE INCH A6 1323

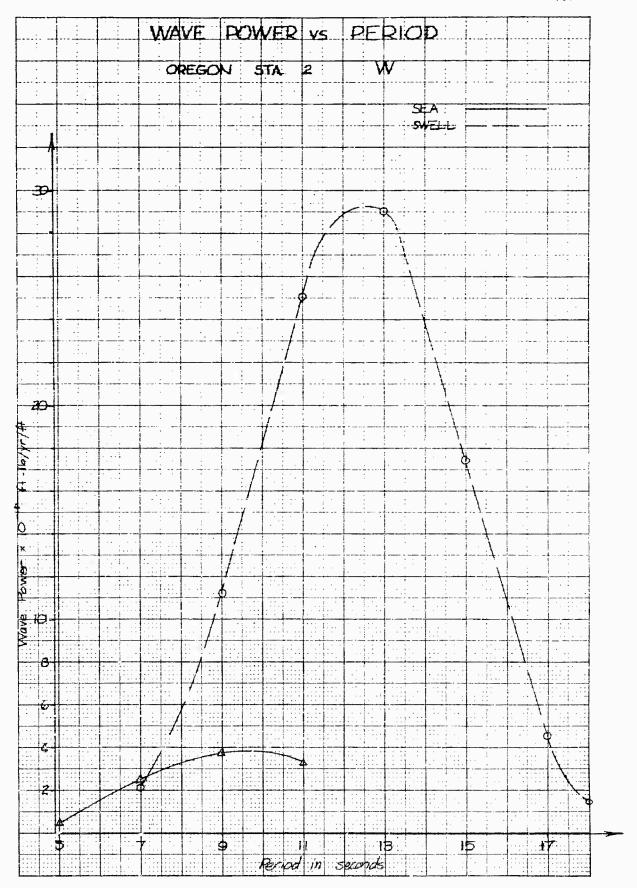


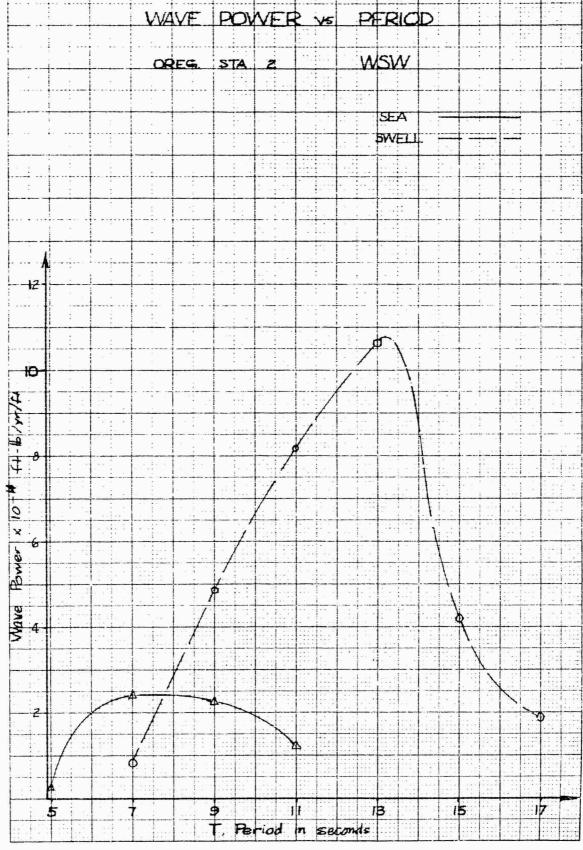
12 x 10 10 1 1 1 1 1 4 5 1 3 2 3



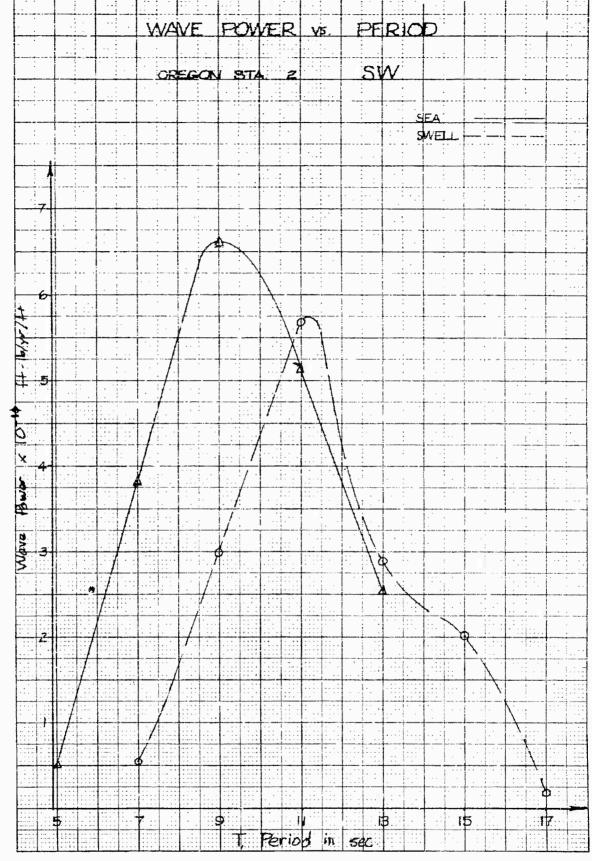


10 x 10 TO 11 NCH 46 1323

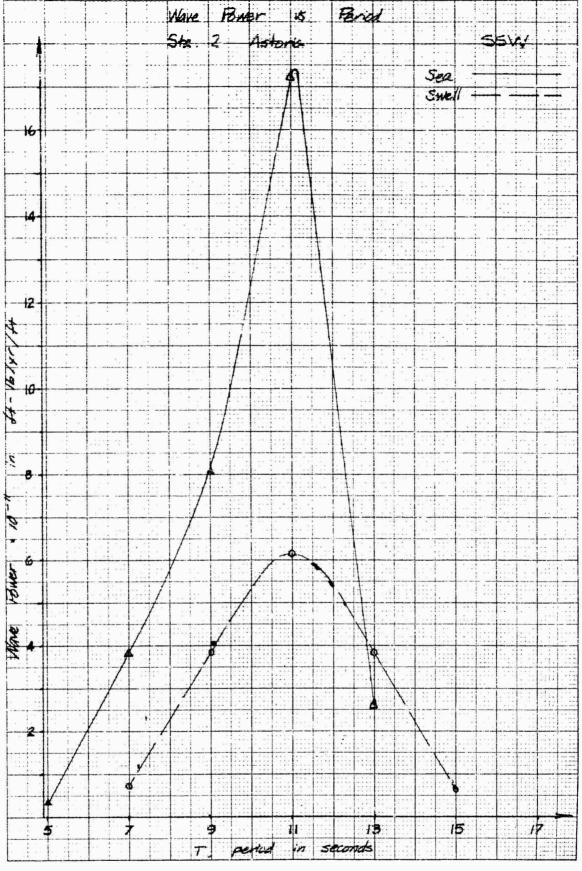




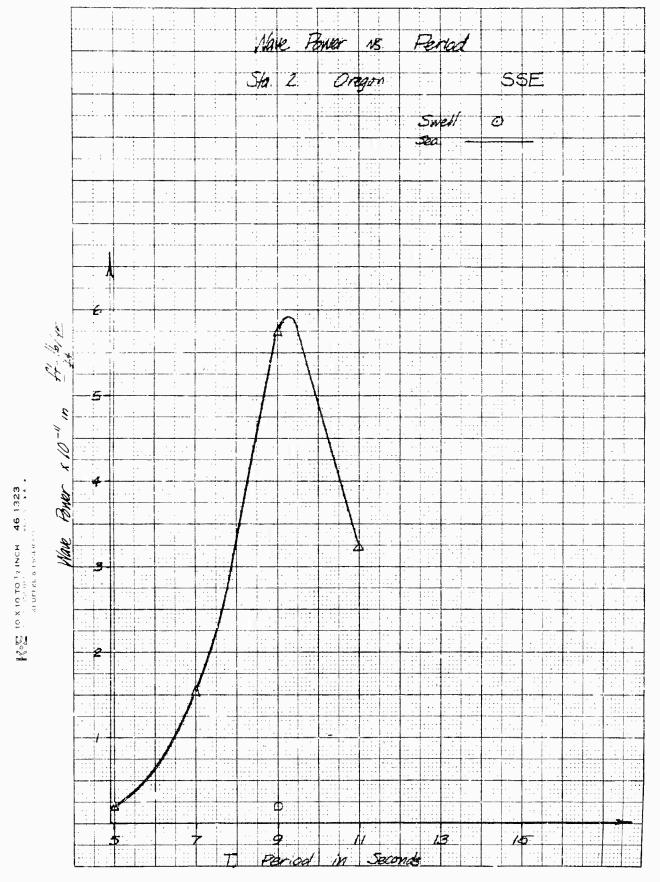
AM TO X TO TO PAINCH 46 1323



Mario X 10 TO 12 INCH 46 1323



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A-101

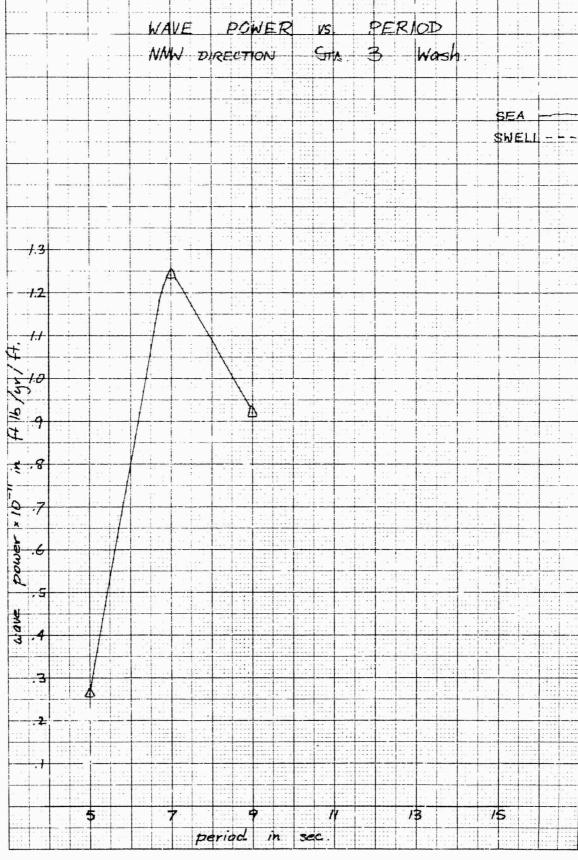
STATION 3 WASHINGTON COAST

Lat. 47° 40'N, Long. 125° 00'W

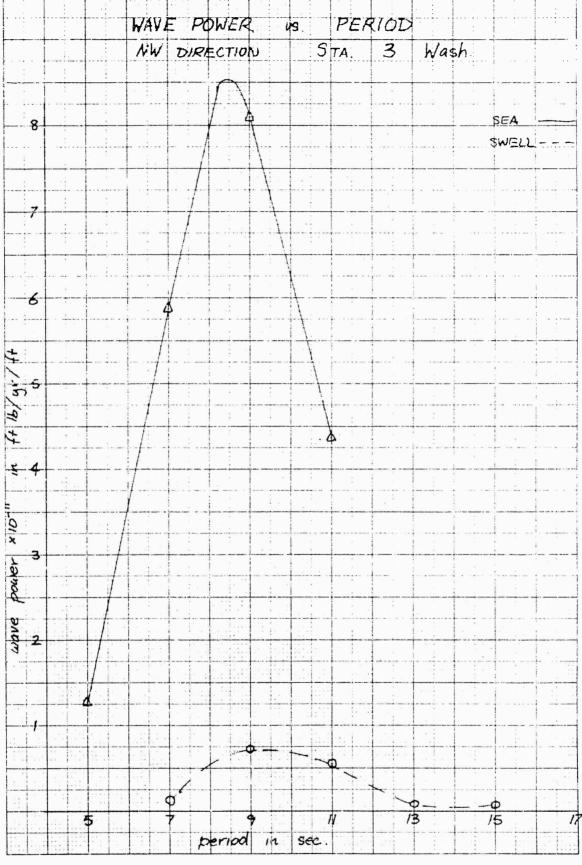
WAVE POWER DIREC VS. 25 STA WASH 90 <del>5</del>5 \$WELL 80 SEA 75 70 4 0. 2 Soluter 35 30 25 20 15 HO SW WSW SSW S SSE Ν NNW NW WNW W A-102

MATTER TO X TO TO V2 INCH 46 1329

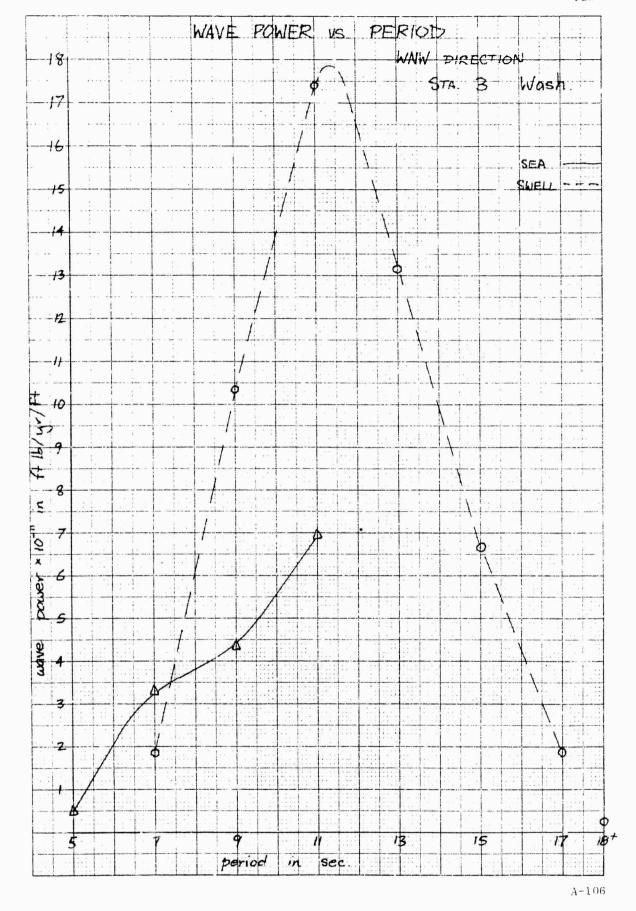
<del>daa</del>



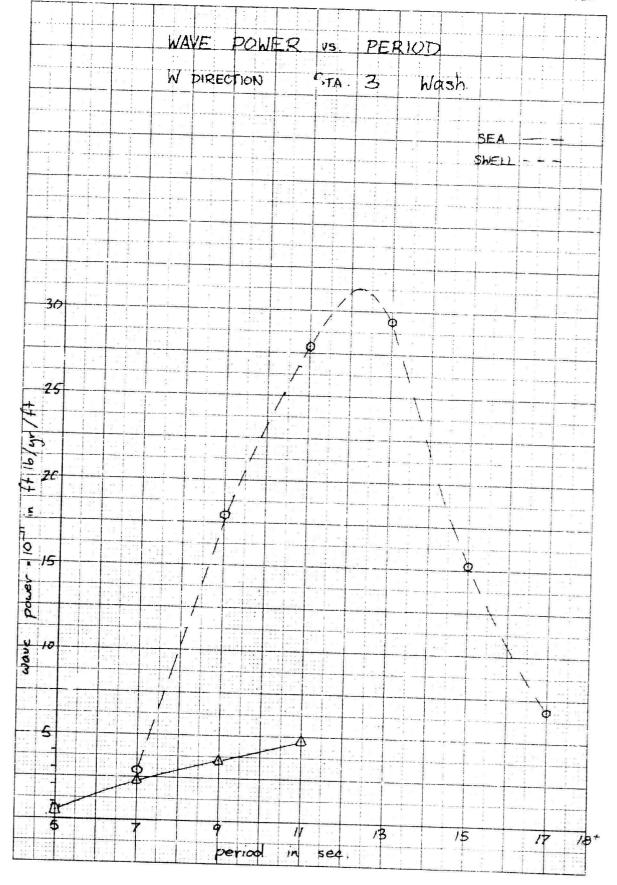
Marie 19 X 10 TO 19 INCH 46 1323

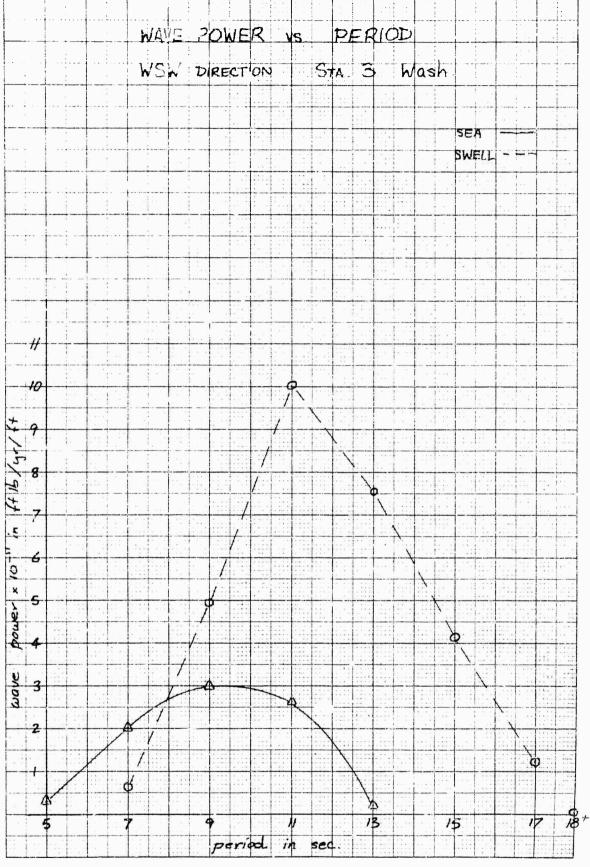


A-105



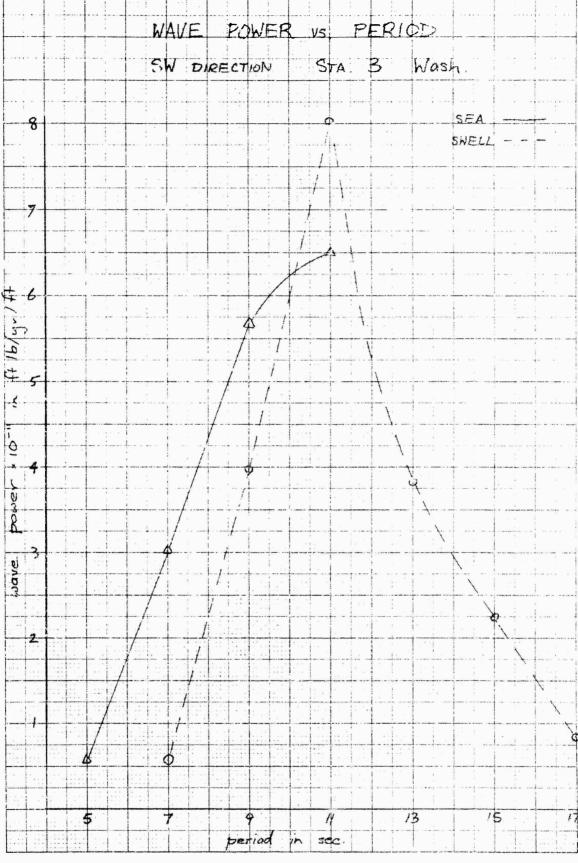
11 10 10 1 X 11 2 X



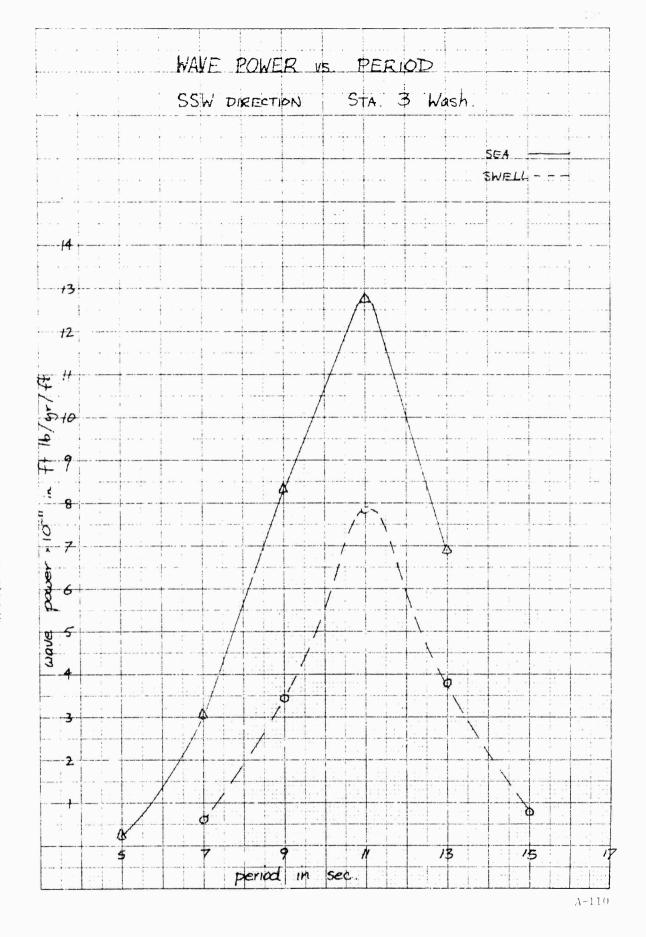


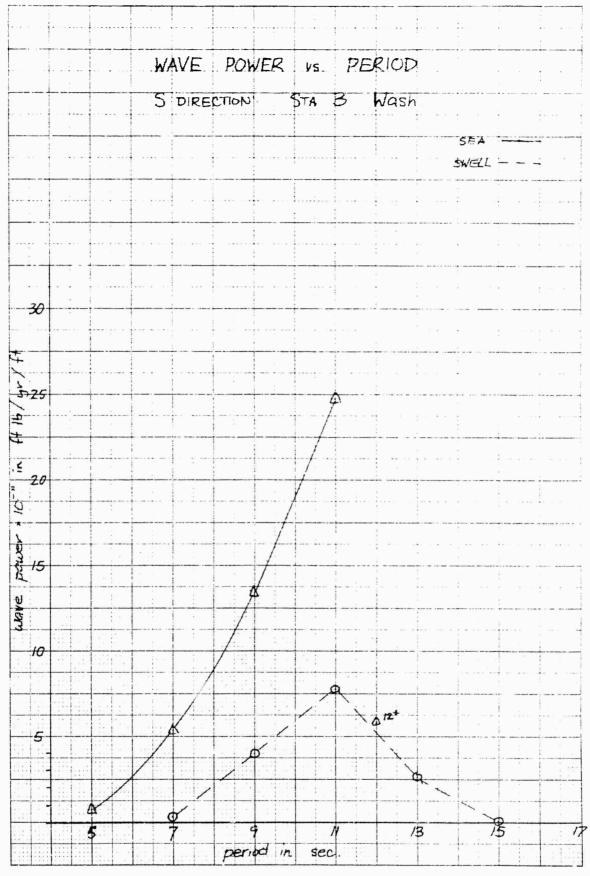
MAG 10 X 10 TO 1 INCH 46 1323

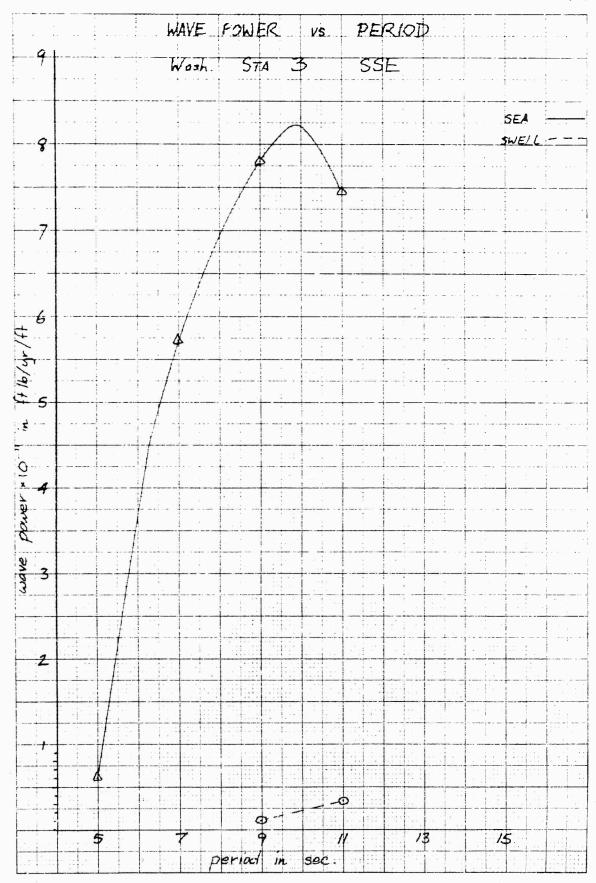
A-108



Moderation 12 Inch 46 1323







## APPENDIX B

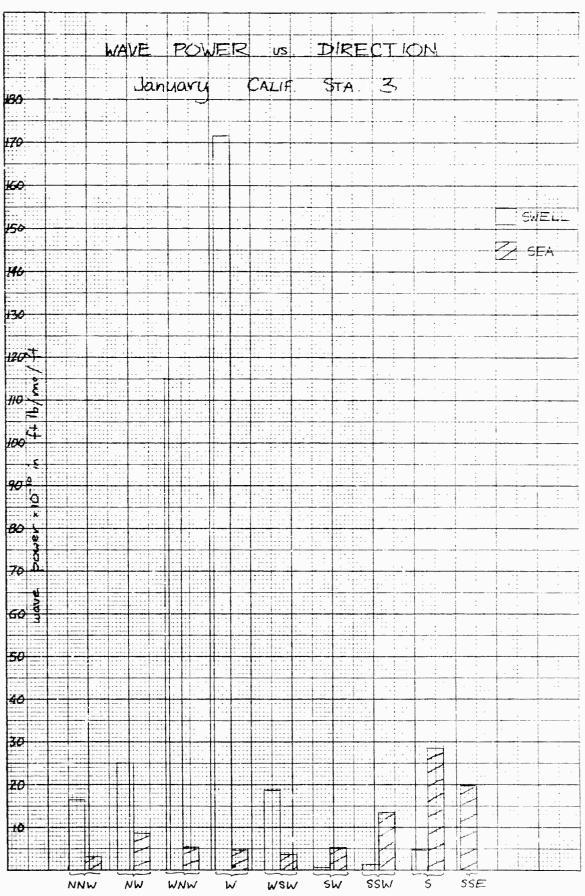
WAVE POWER FOR VARIOUS MONTHS

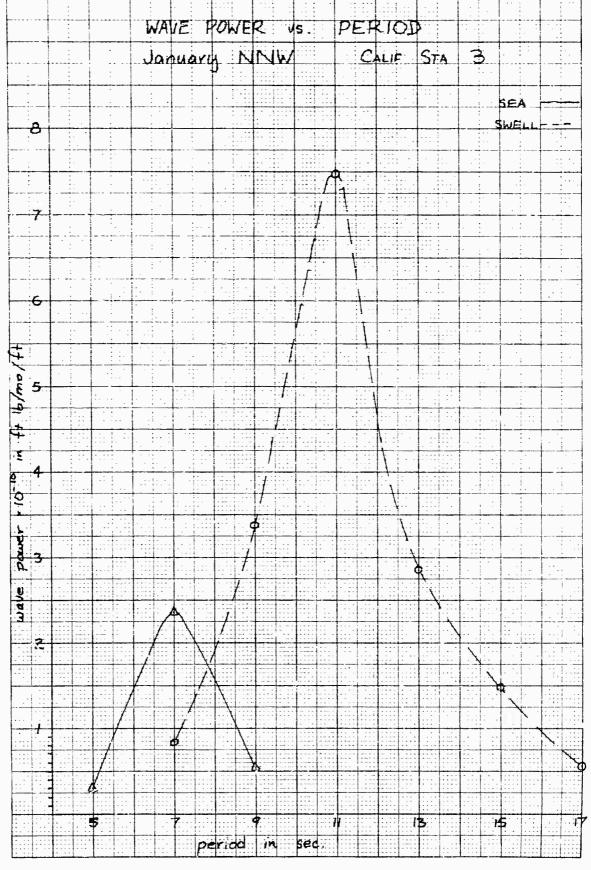
STATION 3 - CALIFORNIA COAST

Lat. 37.6°N Long. 123.5°W

STATION 3 - JANUARY

HALT TO TO VE INCH 46 1323
TATO INCHES TOTAL SA .





46 1323

SEA .... - : : : :: . - 1:: · . . : . . . . . ::. .... . 1 . . # 10 . : -.5 0/ × ٠..:

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January

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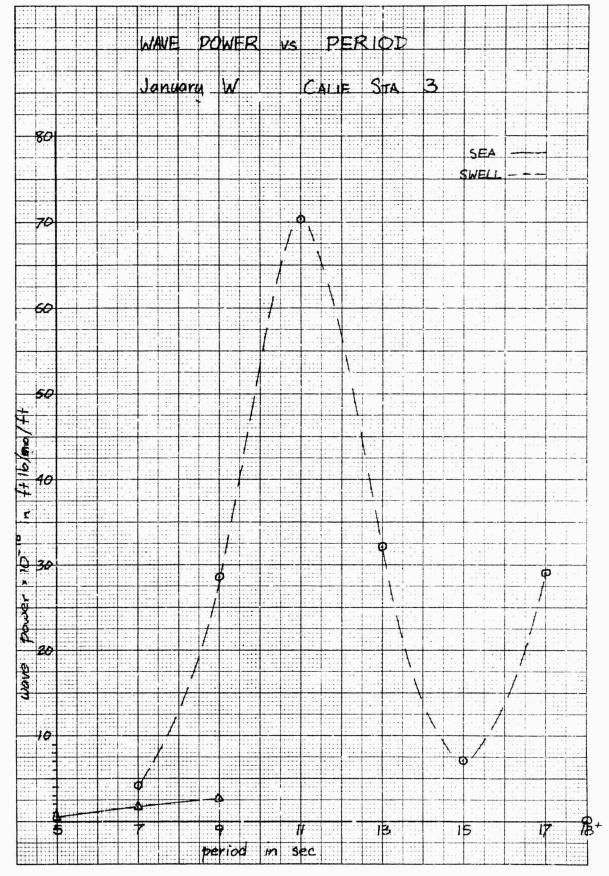
15

13

PCWER WAVE PERIOD VS. WNW STA 3 January CALIF ٠: : SEA 40 SWELL 35 1. <del>30</del> : | . 25 10 /mg/ 4 20 .5 2 X. 15 bomen wowe 10 \$ 13 15 period sec. in

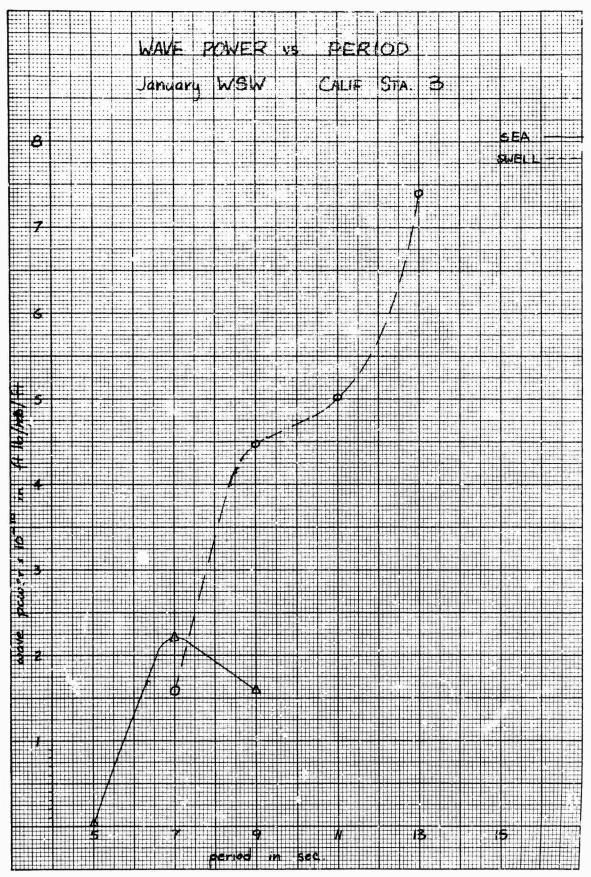
| 46 | 13 X 10 TO 12 INCH 466 1323

KOZ 10 X 10 TO 12 INCH 46 1323 KEUFFEL 3 6250P C.

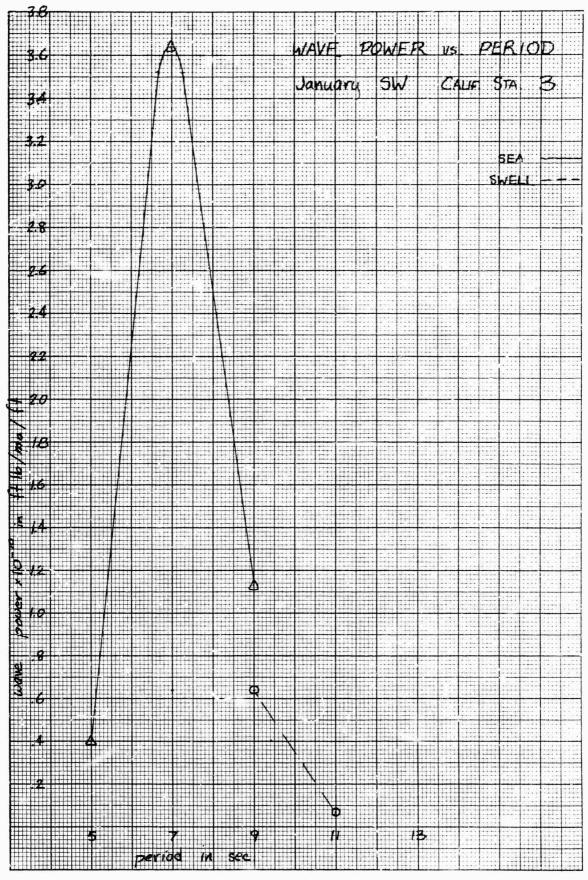


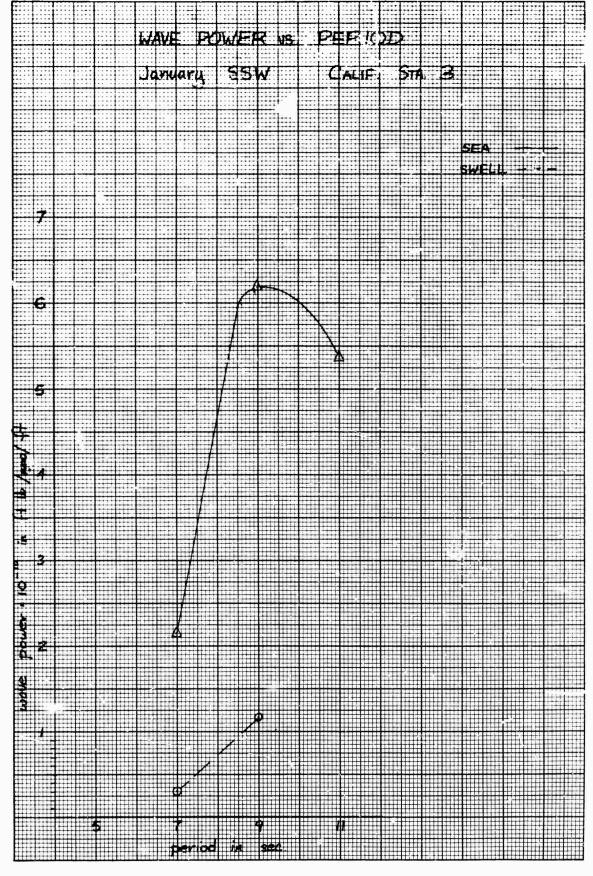
K- 10 X 10 TO 10 INCH 46 1923 7 X 10 INCHES NAST MULLA . REUFFEL & KESEN CO.

1 1 2

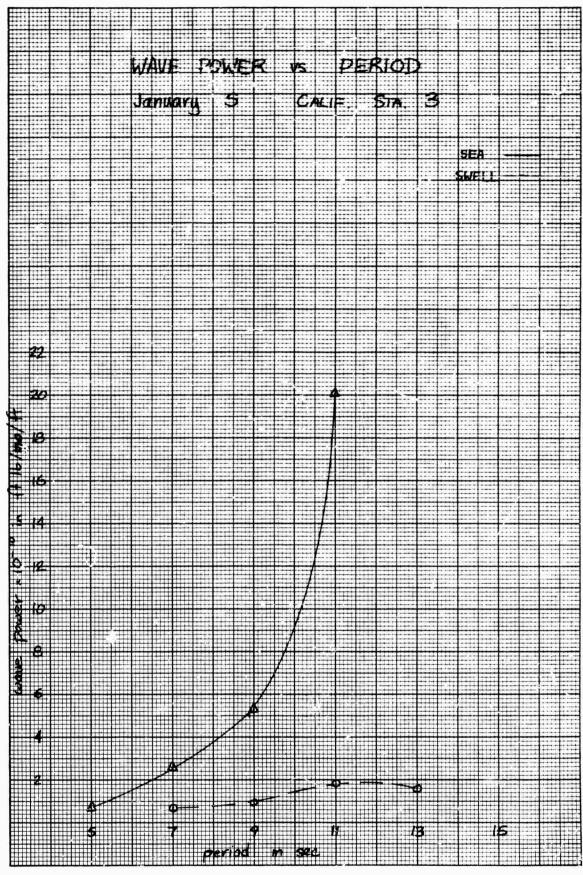


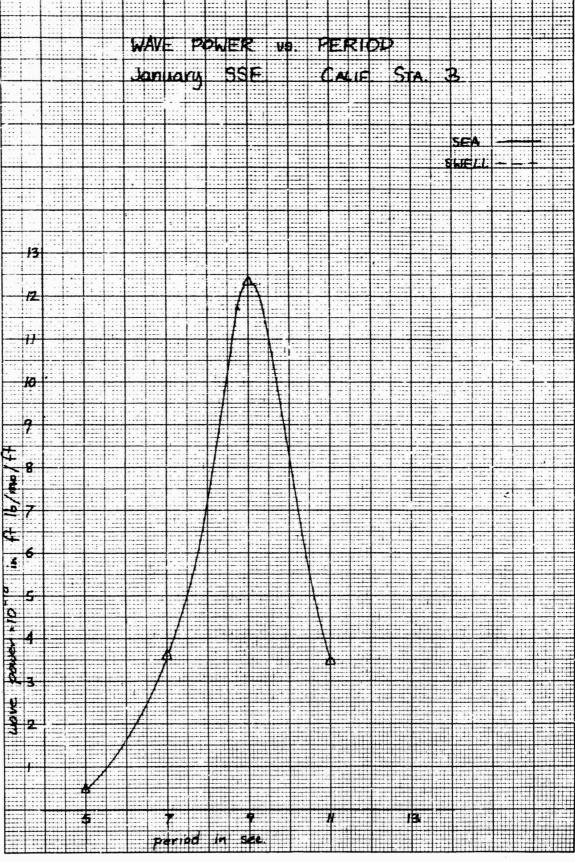
KON 10 X 10 TO 1/2 INCH 46 1323
AND 1 X 10 INCHES HARE IN U.S.A. KEUFFEL A ESSER CO.





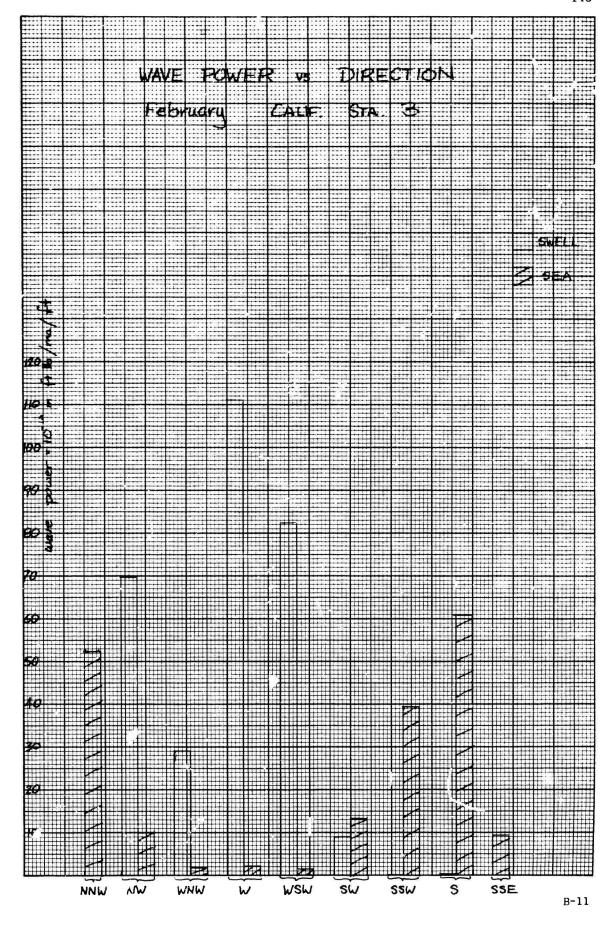
K-E 10 X 10 TO V INCH 46 1323 KEUPPEL & ESSER CO.





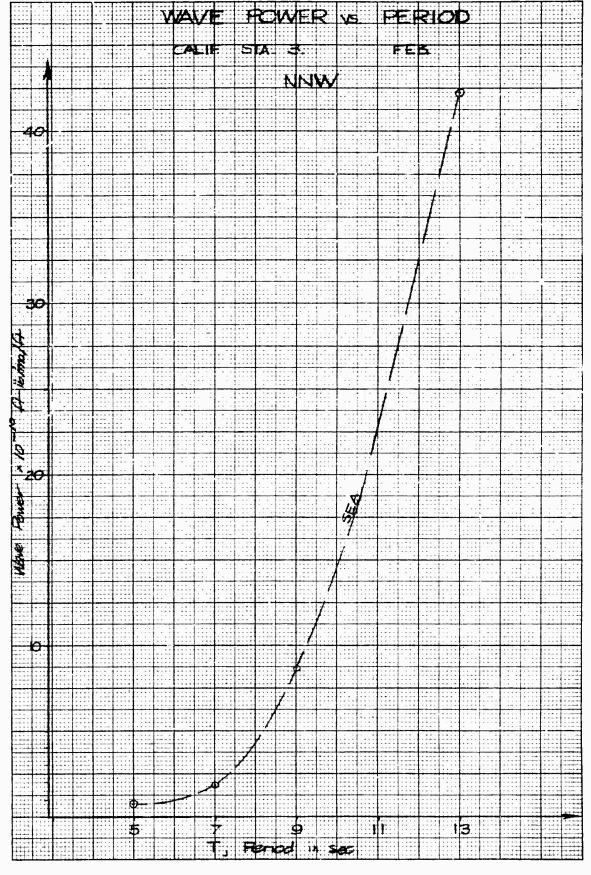
KOE 10 X 10 TO 12 INCH 46 1323 REUFFEL A ESTER CU. . KEUFFEL A

STATION 3 - FEBRUARY



K-M 10 X 10 TO 12 INCH 46 1323

X X 10 INCHES ASSENCE.



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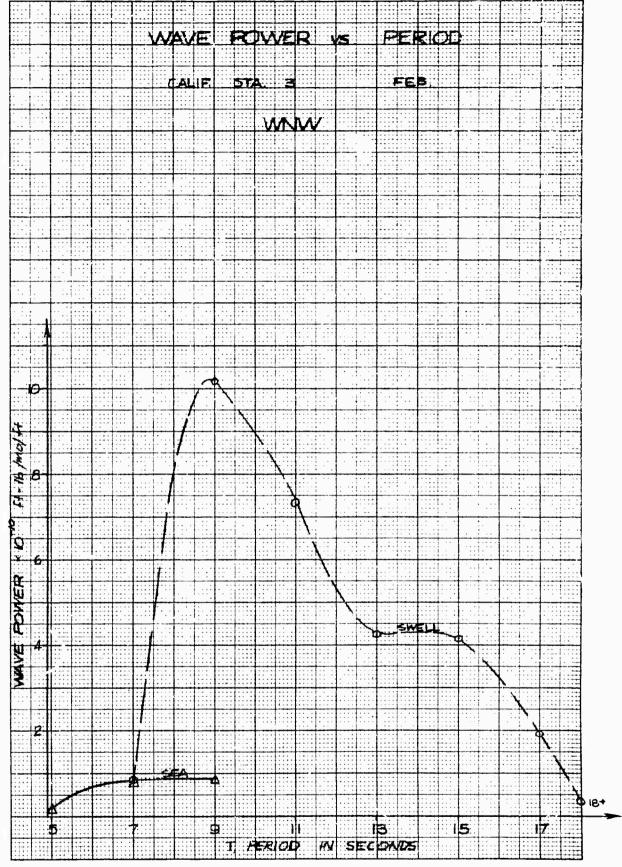
vs

KOE 10 X 10 TO 12 INCH 46 1323
KEUFFEL & ESSUR CO.

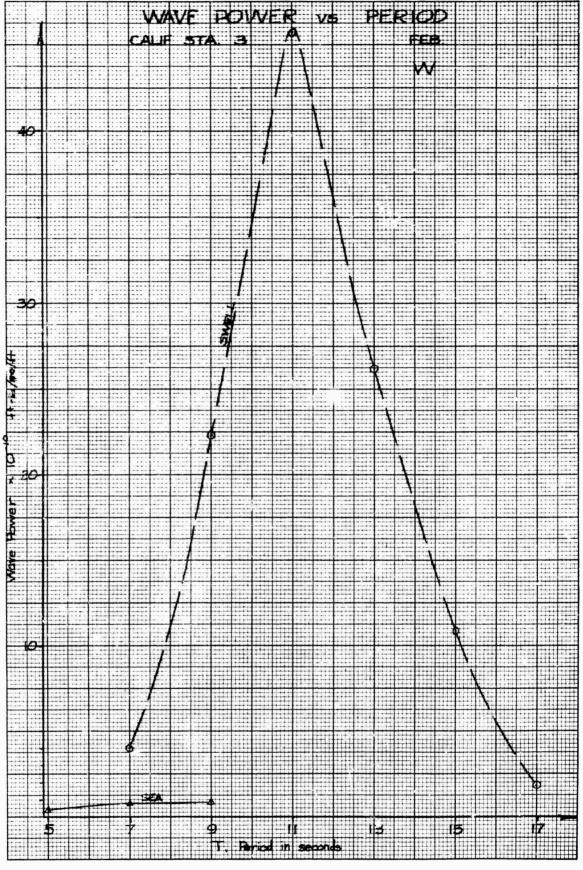
17

15



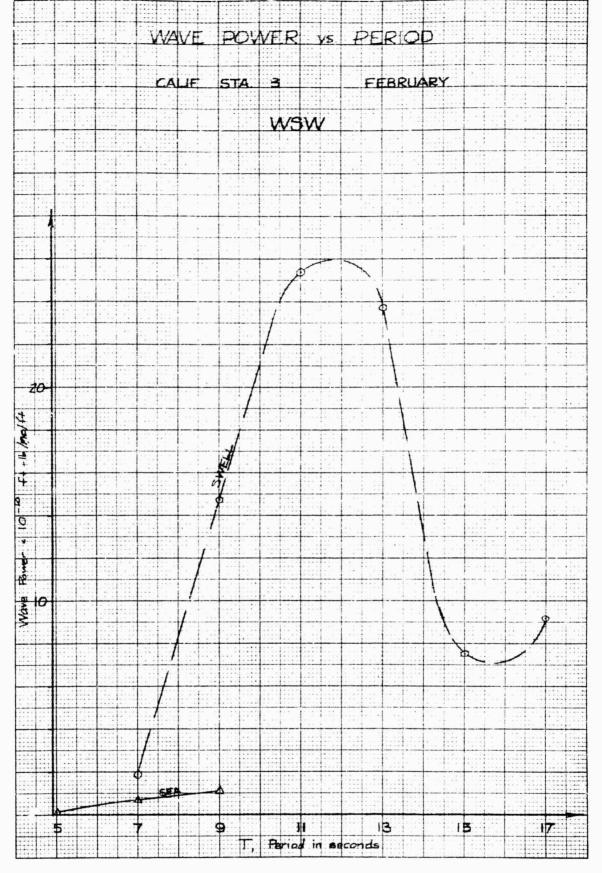


B-14

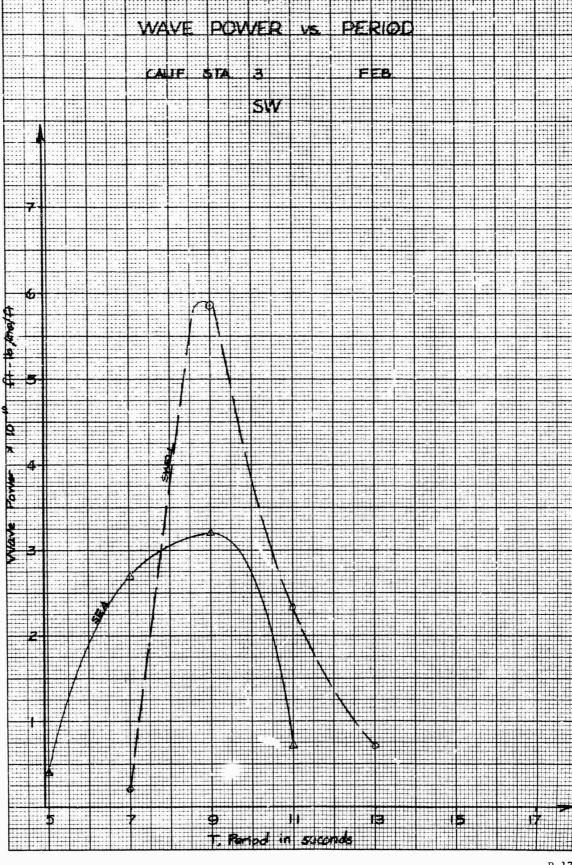


KOE 10 X 10 TO \$2 INCH 46 1323

KENDINCHES MENULAN.



Kett 10 x 10 TO 12 INCH 46 1323 KEUTFEL & ESSUR CO.

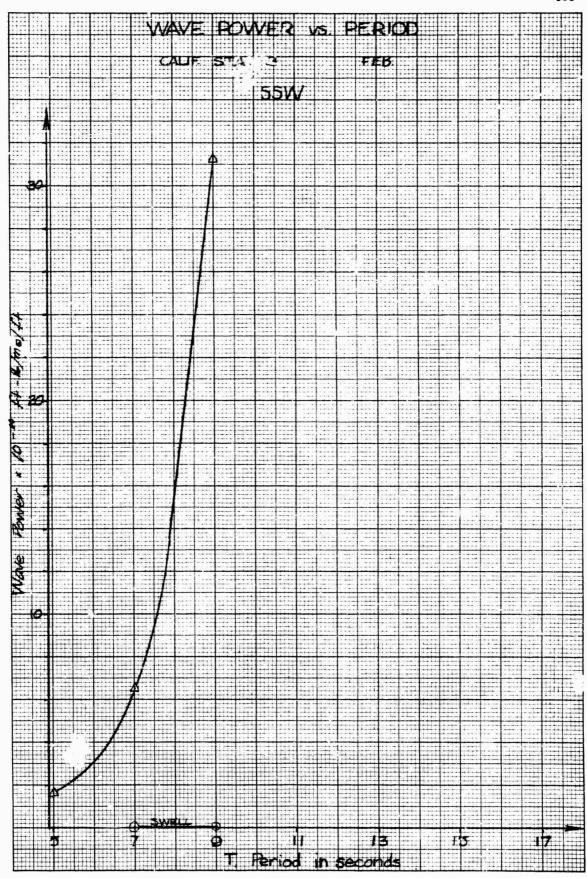


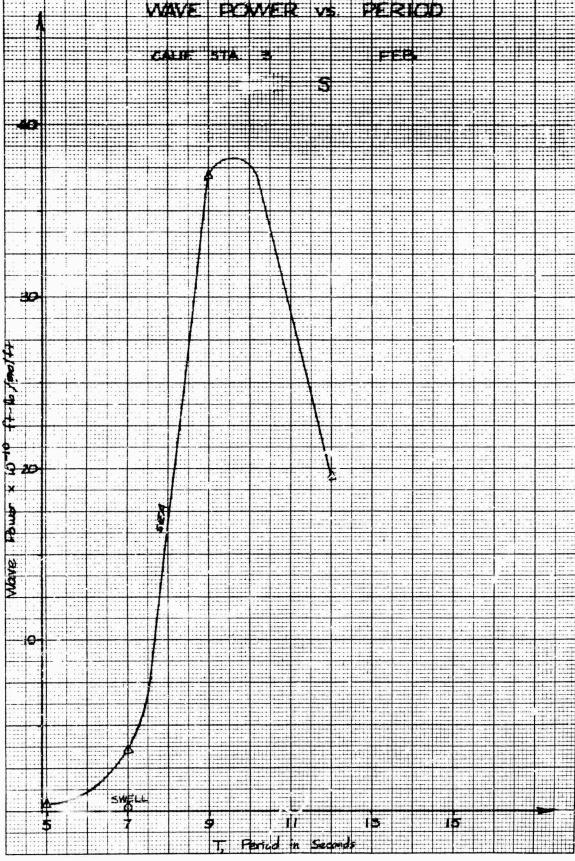
KOE 10 X 10 TO V2 INCH 46 1323
KEUFFEL & ESSER CO.

KON 10 X 10 TO W INCH 46 1323

KON 10 X 10 INCHES

WALFELD ESSER CO.

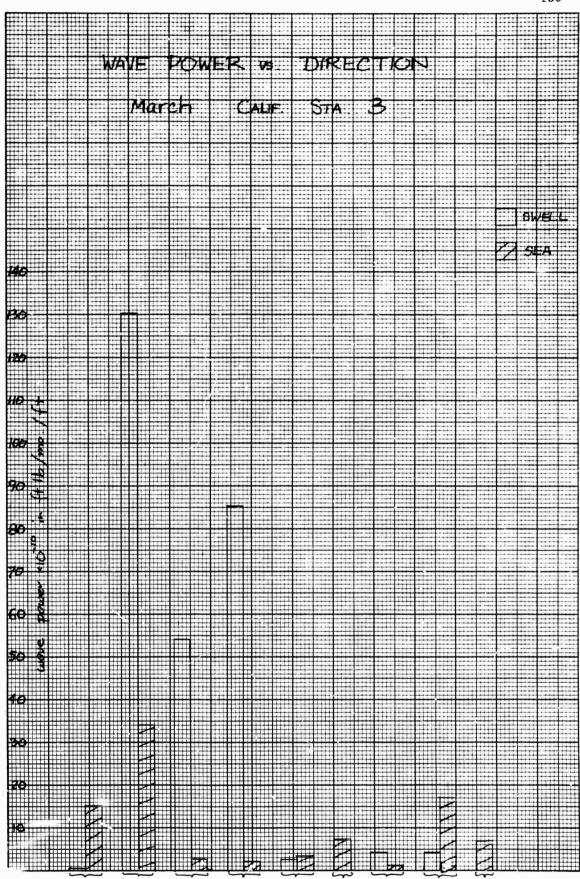


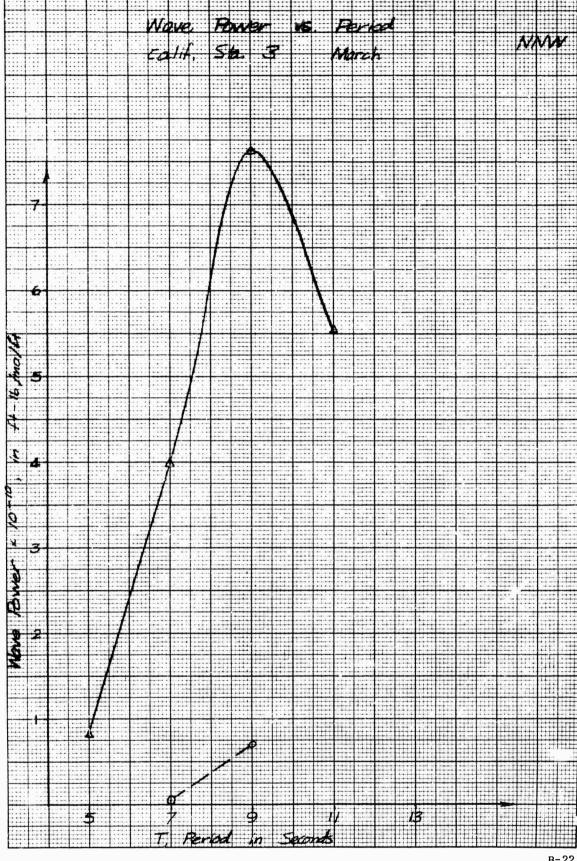


==| POWER SIA 55E 2 4 4 9 3 Wave Power H -31 Flerre 1 in Seconds

KOT 10 X 10 TO 12 INCH 46 1323

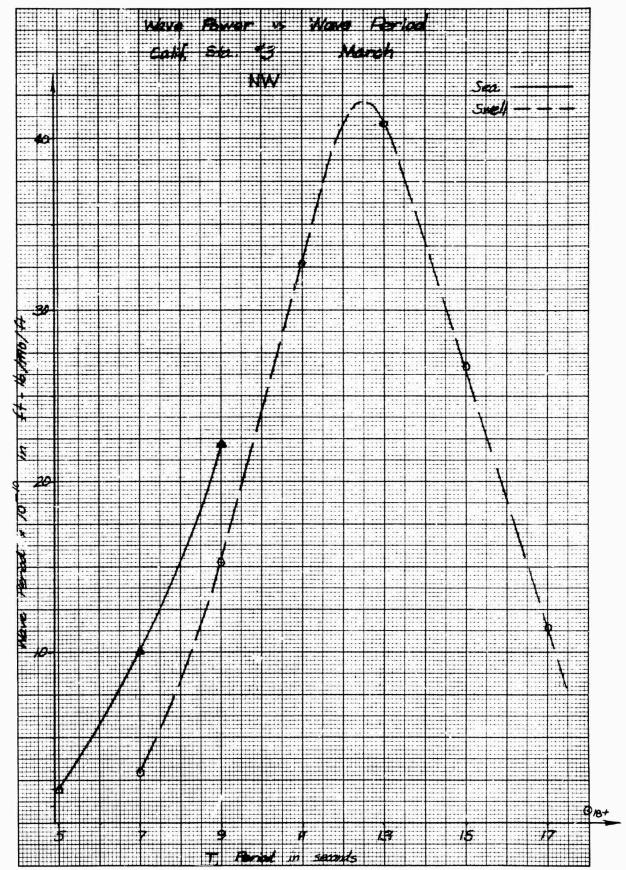
STATION 3 - MARCH

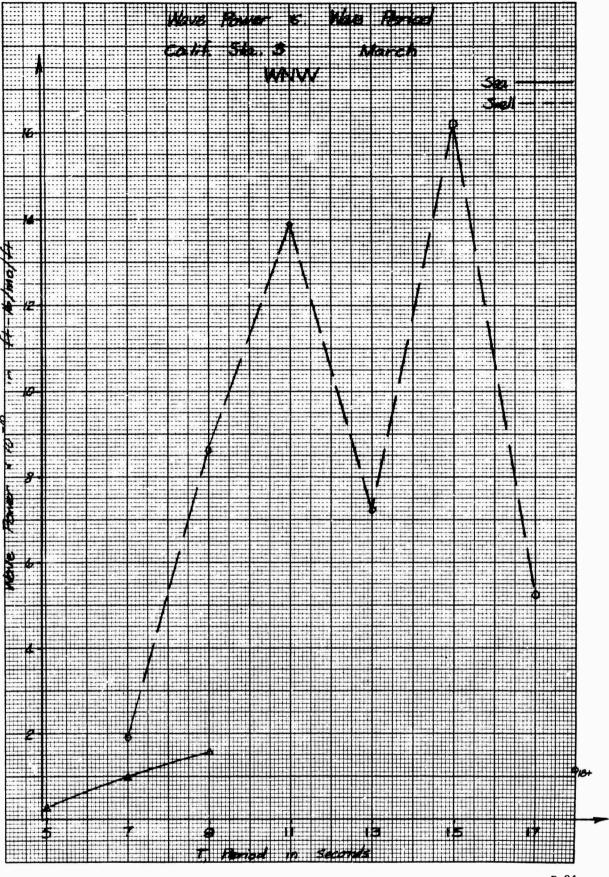


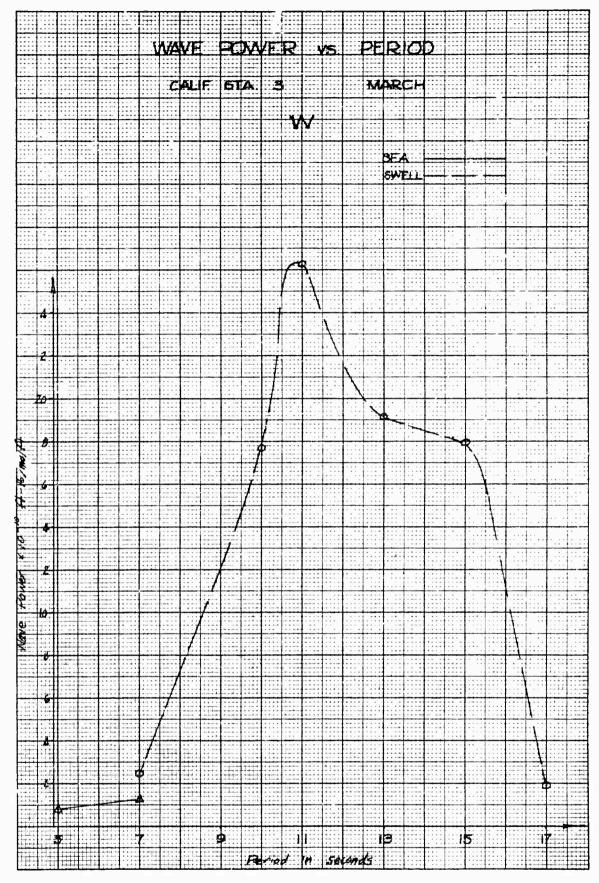


10 X 10 TO V2 INCH 46 1323 1 X 10 INCHES WILL IN U.S.A. REUFFEL & ESSER CO.





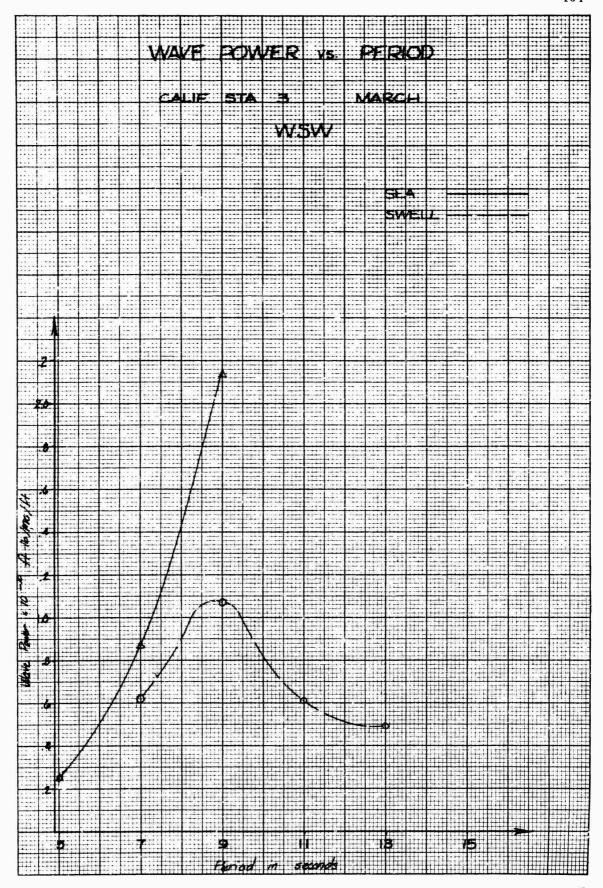




K+E 10 X 10 TO 1/2 INCH 46 1323

K+E 1 X IN INCHES

KEUFFEL & ESSER CO.



WAVE POWER PERIOD MARCH **SW** ::: i. :::: :.. ---HIH 4 ::: 15 Period in seconds

KOE 10 x 10 TO V2 INCH 46 1323

KOE 1 x 10 INCHE.

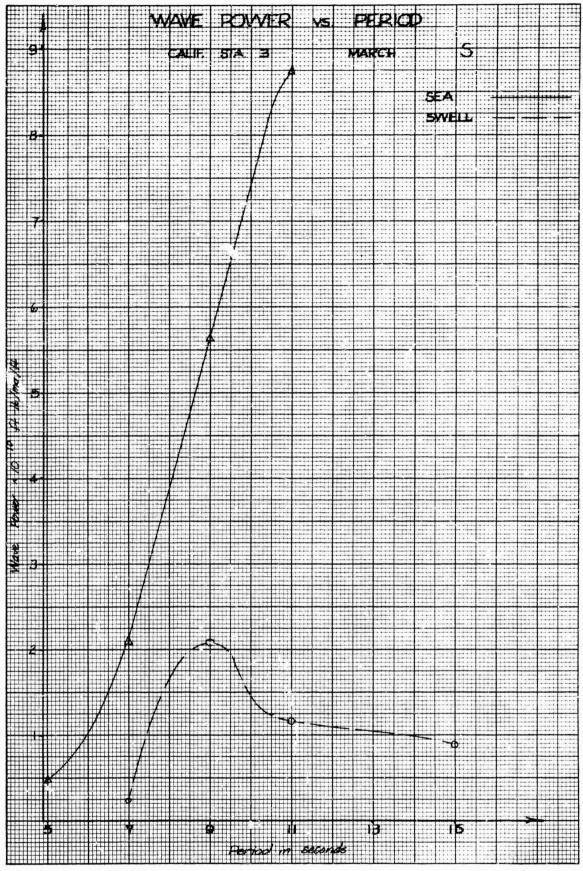
KEUFFEL 0 ESSER CC.

STA SE.A A. 16 May 14. M \* Ware **Ø** 13 seconds

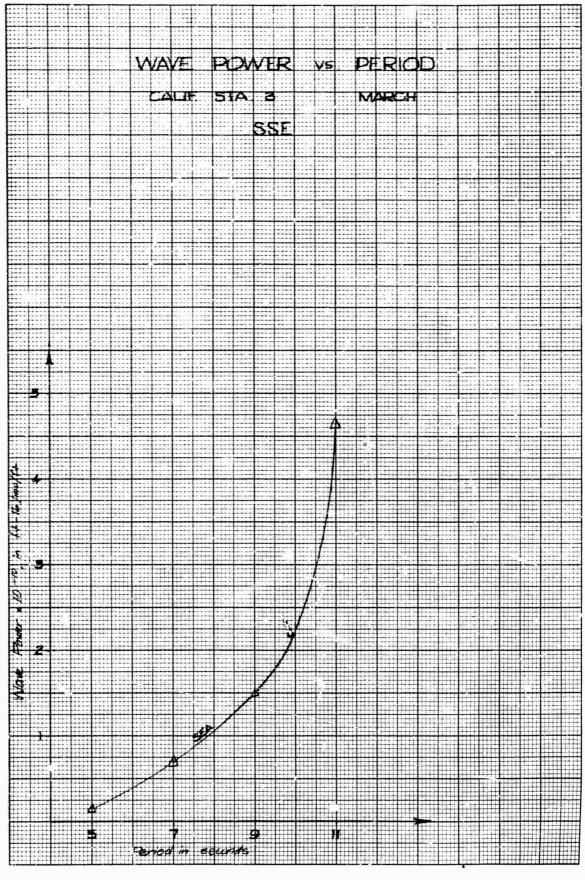
TO X 10 TO 10 INCH 46 1323
7 X 10 INCHES RACELULA.
KEUFFEL & ESSER CO.

K-E 10 X 10 TO 1/2 INCH 46 1323 X 10 INCHES MARIN U.S.A. KEUFFEL & KEUFFEL & KEUFFEL

10



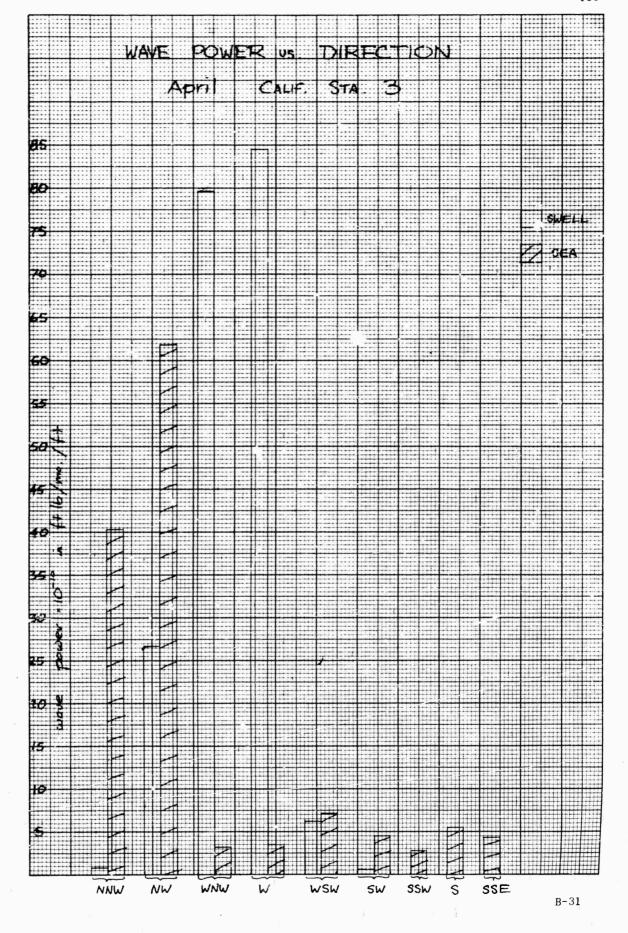
B-29



K-M 10 X 10 TO V2 INCH 46 1323

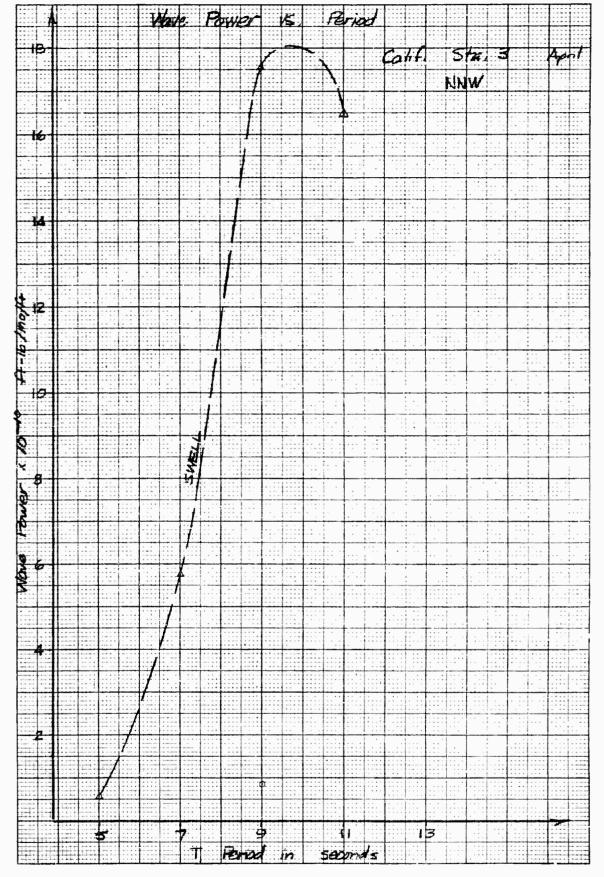
X X 10 INCHES ASSET 0.

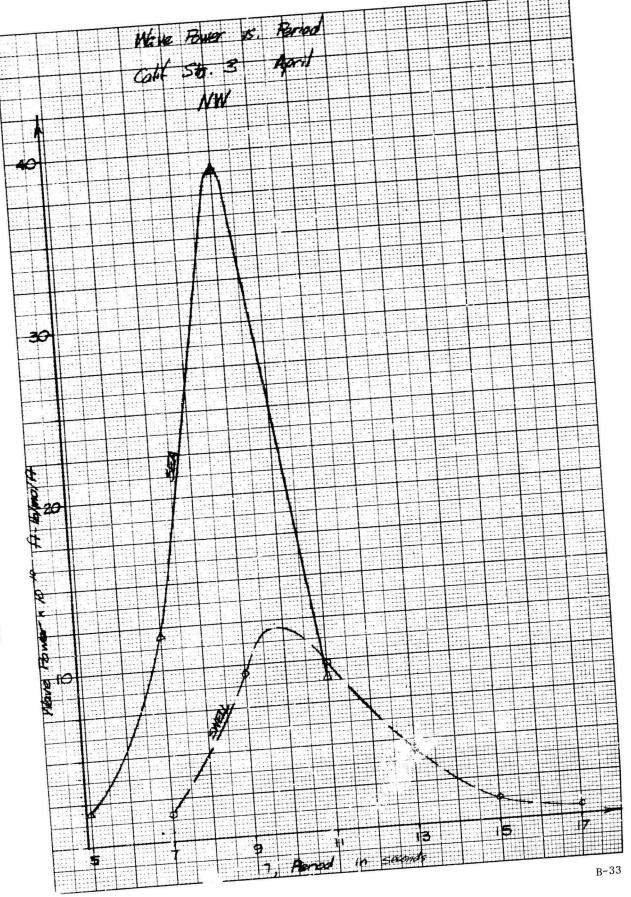
STATION 3 - APRIL



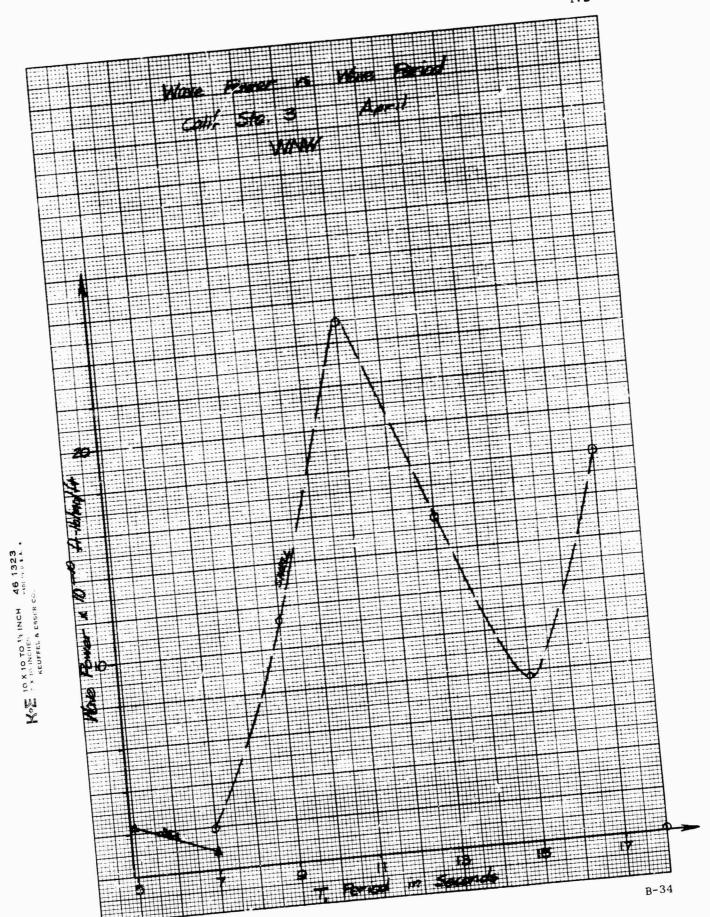
AM TO X TO TO VE INCH AG 1923

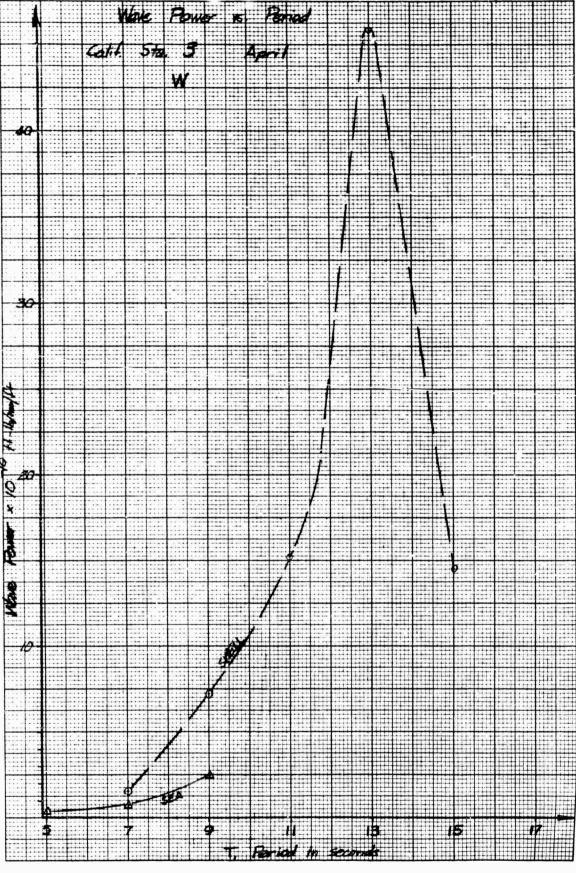
KOE 10 X 10 TO 12 INCH 46 1323





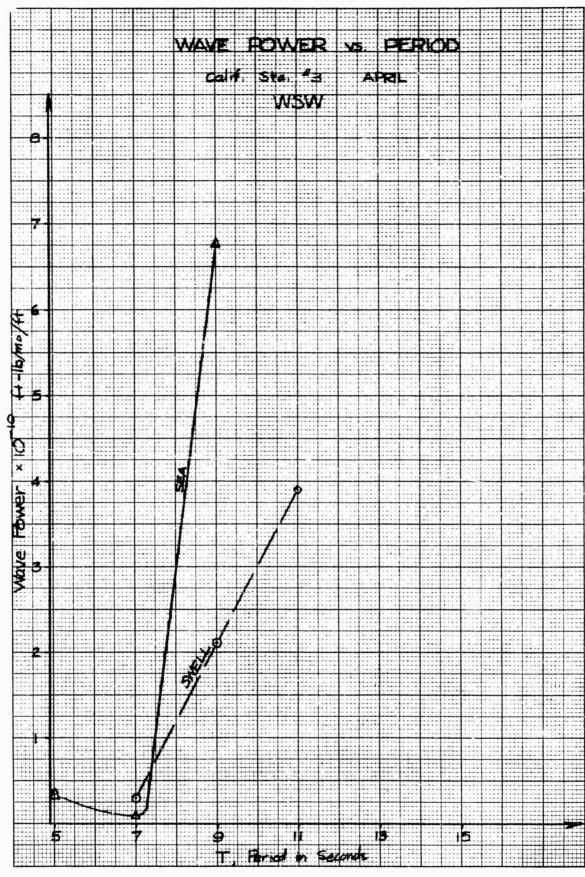
Kor 10 x 10 TO 17 INCH 46 1323

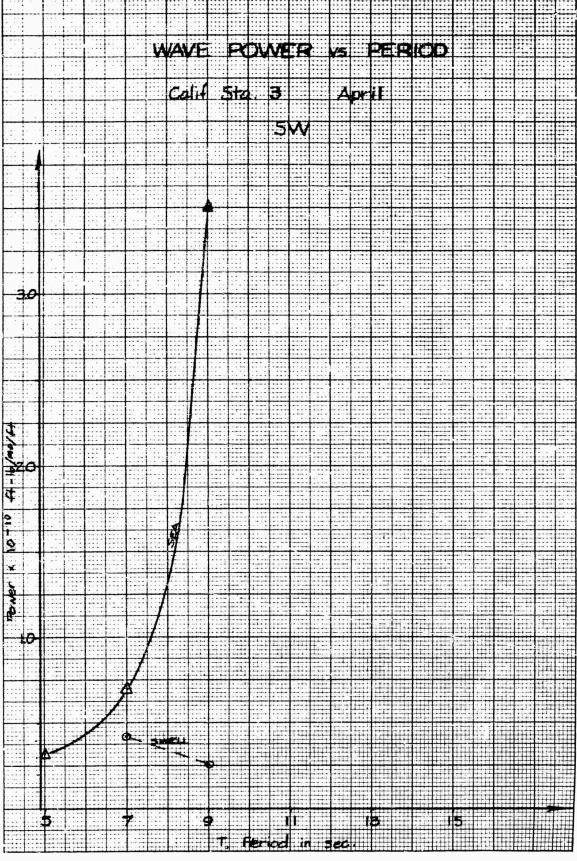




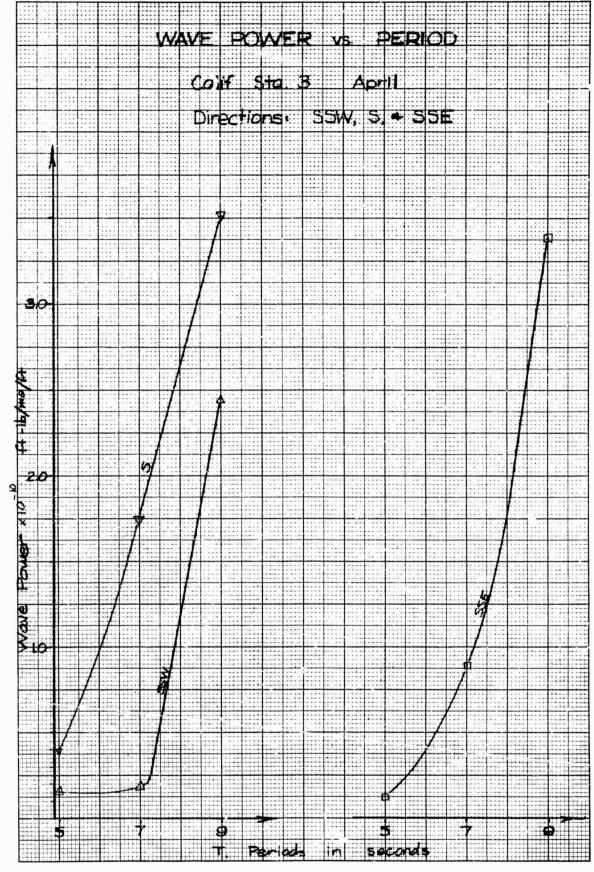
KOE 10 A 10 TO 13 INCH 46 1323
KEULINCHES WILLIA 1 A KEUFELA ESSER CO.







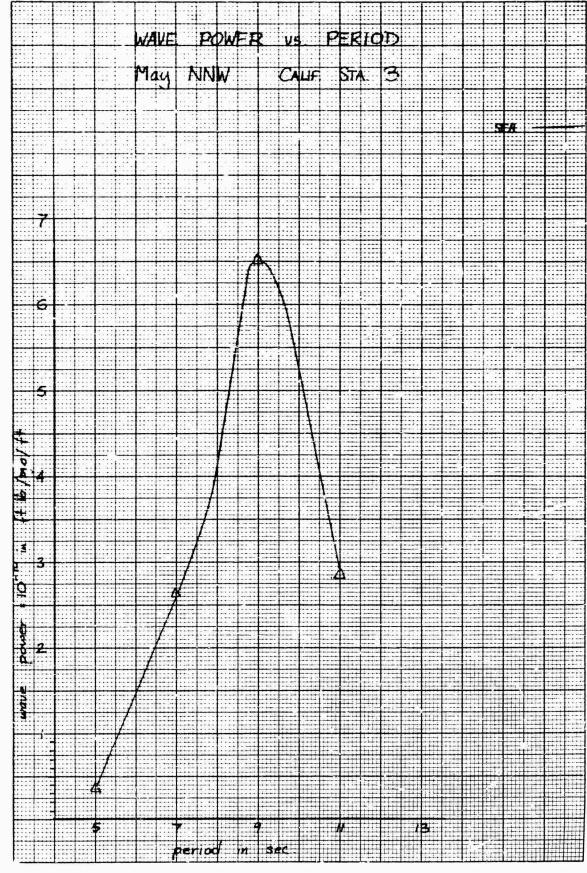
KOE TO X TO TO TO TO THE HEAT AGE TO STATE OF THE METERS A SECTING OF THE METERS AS THE CO.

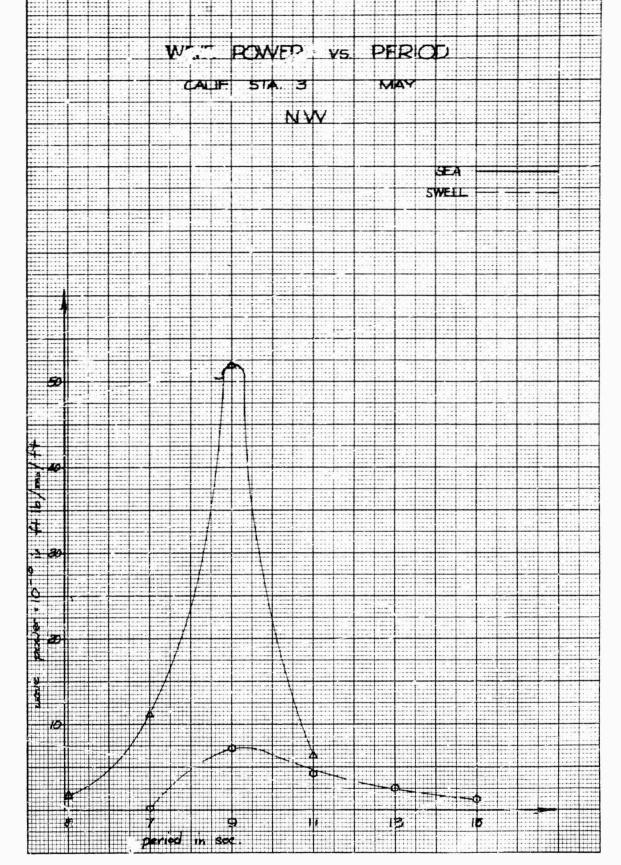


STATION 3 - MAY

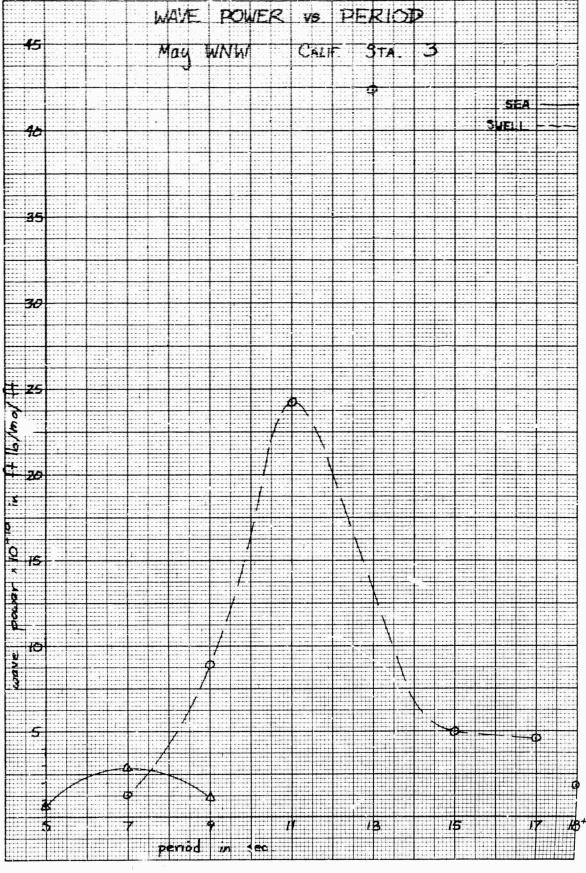
MAVE DIRECTION WAVE POWER VS 51A. MAY 5WEL BO 70 16 9 66 Buer 50 140 20 NNW NW WNW W WSW 5W 55W S SSE B - 39

10 X 15 TD N2 INCH A6 1928 7 X 10 INCHES AAST WUELA KEUFFEL & KOSER CO.





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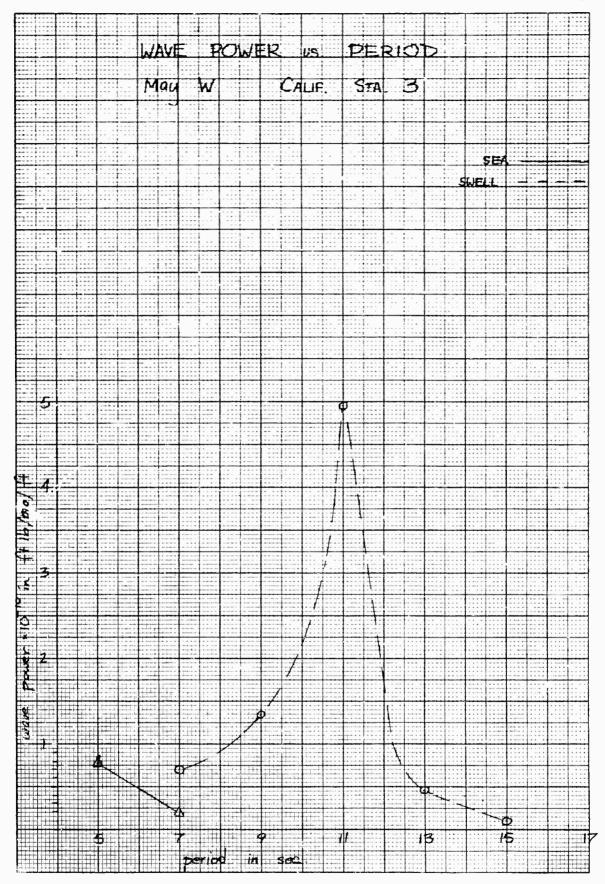


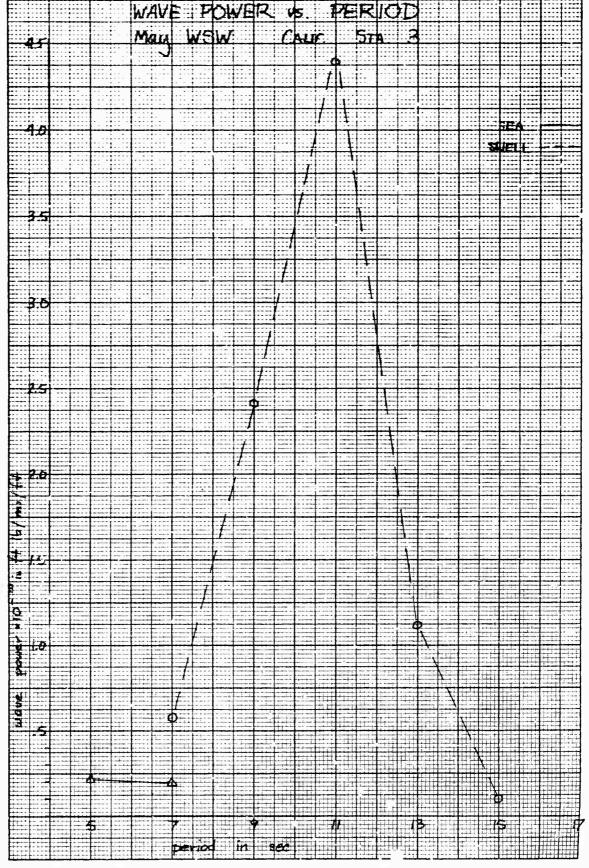
Kor 10 x 10 TO V2 INCH 46 1828

Kerrele esser 50.

KOM 10 X 10 TO 1/2 INCH 46 1320

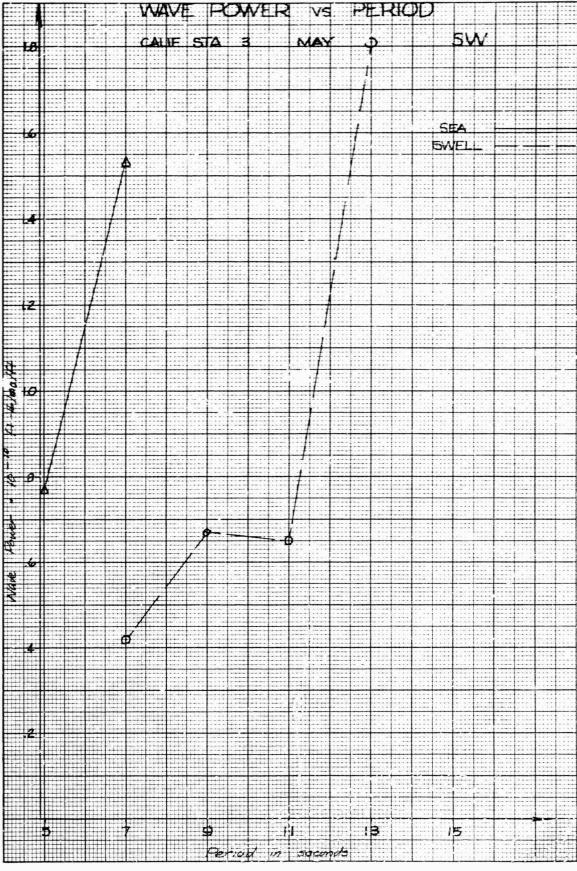
XAD 7 X 10 INCHES XOSIN U.S.A.





K-E 10 X 10 TO V2 INCH 46 1323 REUFFEL & KREEF CO.

.11



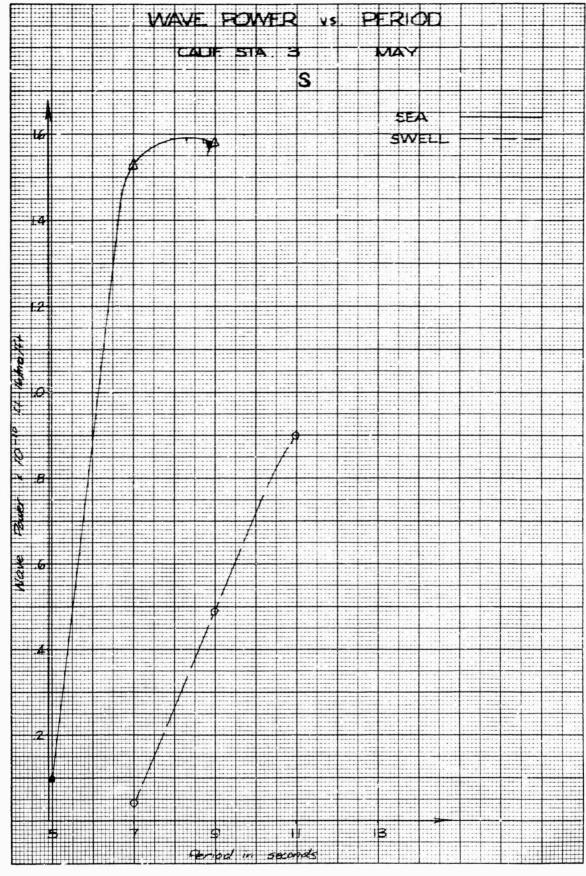
K\*E 10 X 10 TO V2 INCH 46 1023

A 10 X 10 INCHES ASSENCE.

WAVE POWER PERIOT SSW Mau CALIF STA. 3 SEA # 11 1.0 10 × ¥ .4 94 2 3 2 

K-M 10 X 10 .7 V INCH 46 1329

KEUFFL & CORR CO.



KAT 10 X 10 TO V2 INCH 46 1328

REPERENT MENT OF THE OF TH

STATION 3 - JUNE

SWELL 160 140 ₽G 01-0 × 100 Buer K\*M 10 X 10 TO 12 INCH 46 1323

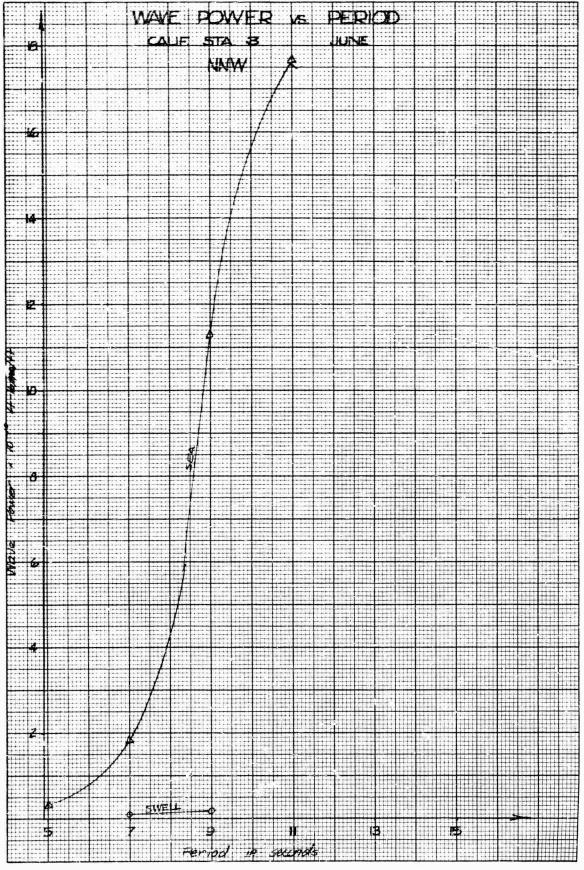
KEUPINGHES MADEIN UNA KEUPINGHES SERR CO. Monthly 7542/ 8 NNW NW WNW WSW SW SSW S W B-49

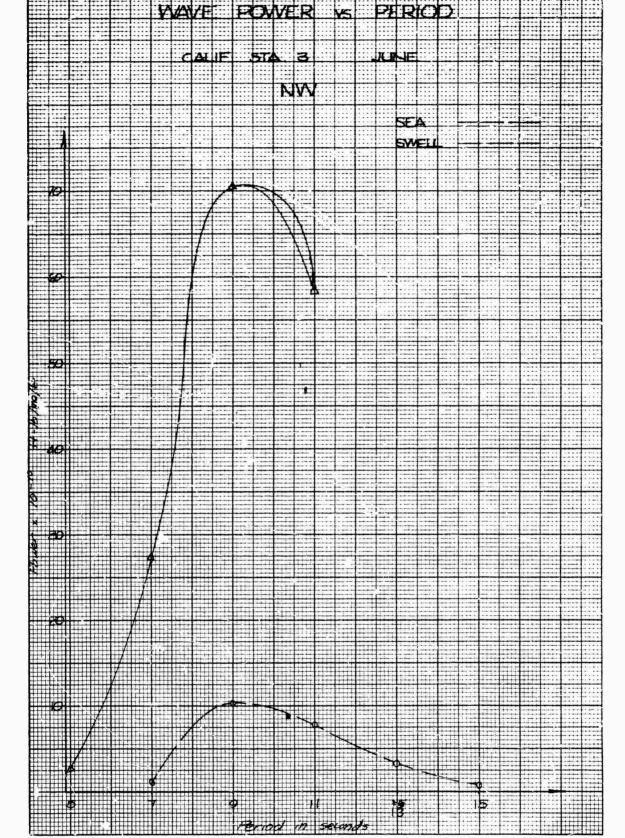
WAVE POWER

DIRECTION

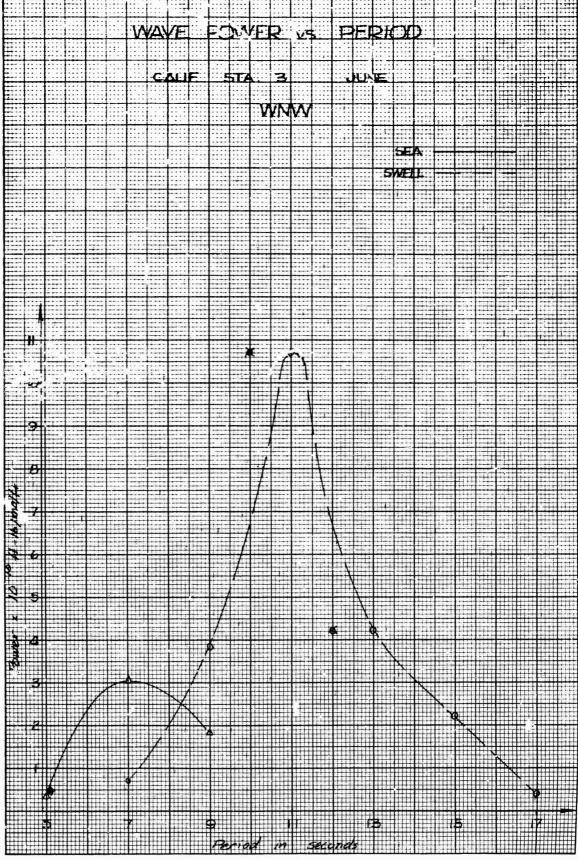
V5.

K-E TX TO HOTHES MANTH USA TREPFEL & ESSERT CO.



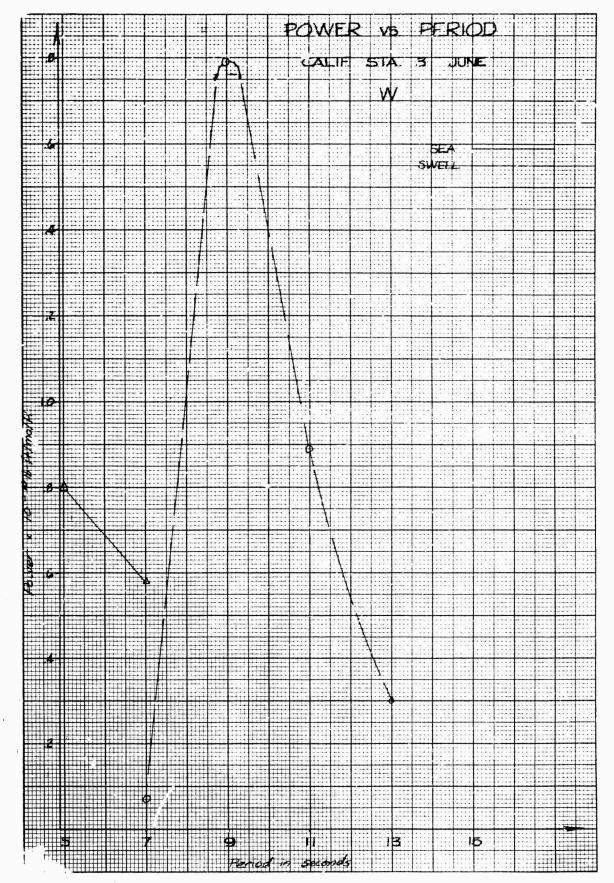


KT T X TO TO VA INCH 46 1323 X X TO INCHES KAREIN U.S.A. . KEUFFEL & ESSER CO.



TAM 10 X 10 TO 1/2 INCH- 46 1323 TX 10 INCHES XARIN U.E.A. . KEUFFEL & 6868 GO.

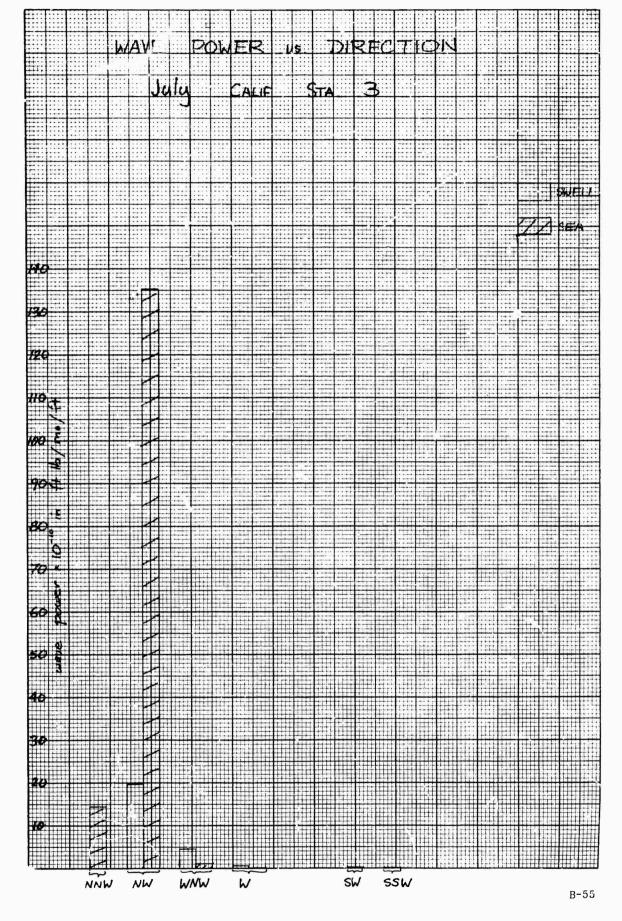




WAVE HINE Period in seconds 

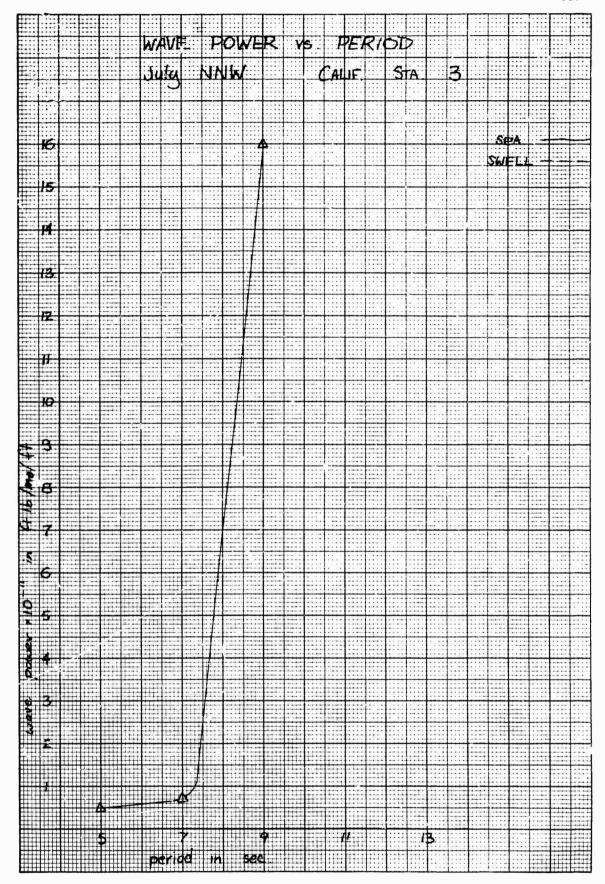
K-M 10 X 10 TO V2 INCH 46 1920
X 10 INCHES PARTICLES CO.

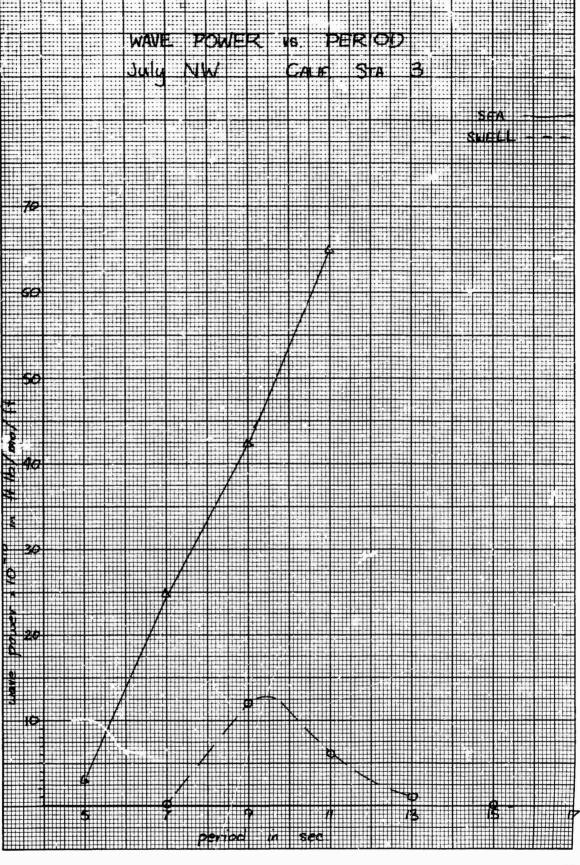
STATION 3 - JULY



TO X 10 TO V2 INCH AG 1020 7 X 10 INCHES HAREN U.S.A. KEUFFEL & ESSER CO.

KON 10 X 10 TO 12 INCH 46 1323
KEUF 2 X 10 INCHES MASSIFILE.A. KEUF EL A KONF CO.





K-E 10 X 10 TO 15 INCH 46 1323 KEUFFEL & ESSER CO.

POWER PERIOD July WNW CALF. STA. SEA SWELL (9) × 

KT 1 X 10 TO V2 INCH 46 1328
T X 10 INCHES MARIN U.E.A. KRUTFEL A ESSER CO.

POWER July W STA CALIF 5 18 Jane 1 114 N. · š **S** nave 

KON 10 X 10 TO V2 INCH 46 1328
TX 10 INCHES MARIN U.E.A. REUFEL & ESSER CO.

KAM 10 X 10 TO V2 INCH 46 1928

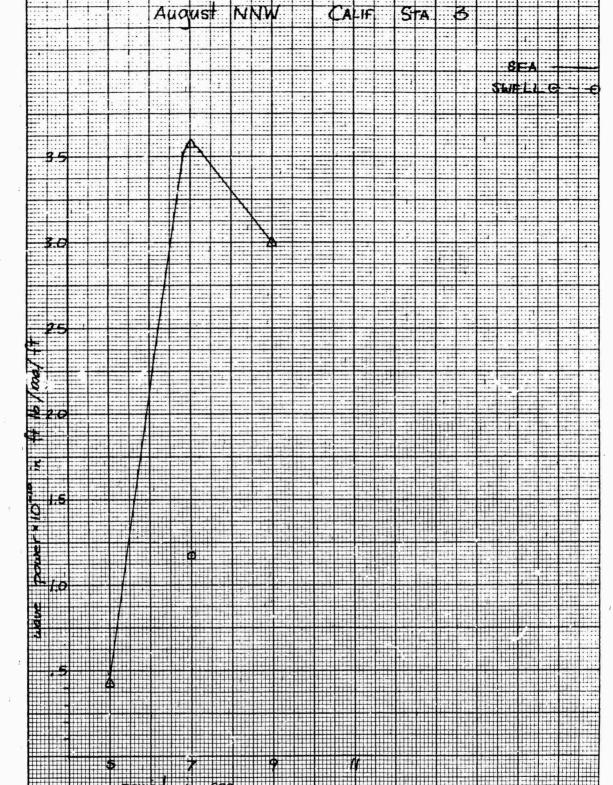
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STATION 3 - AUGUST

WAVE POWER DIRECTION **95** : [ ]: STA 3 CALIE ii. .... i • ; :: :. 2 2 20 ŝ SSE WNLI NNW NW h/ B-61

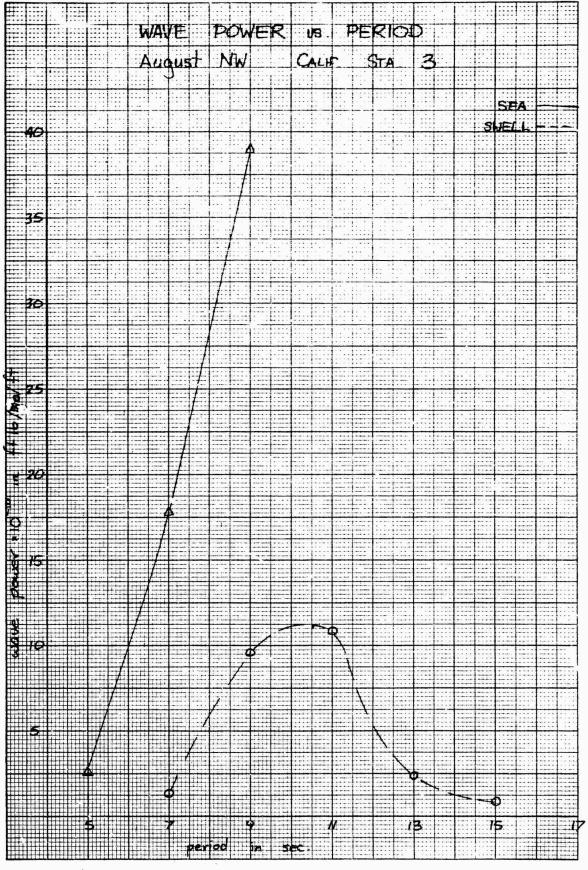
K-K 10 X 10 TO 1/2 INCH 46 1323
KRUFFEL & ESSER CO.



WAVE

KOE 10 X 10 TO M INCH 46 1925

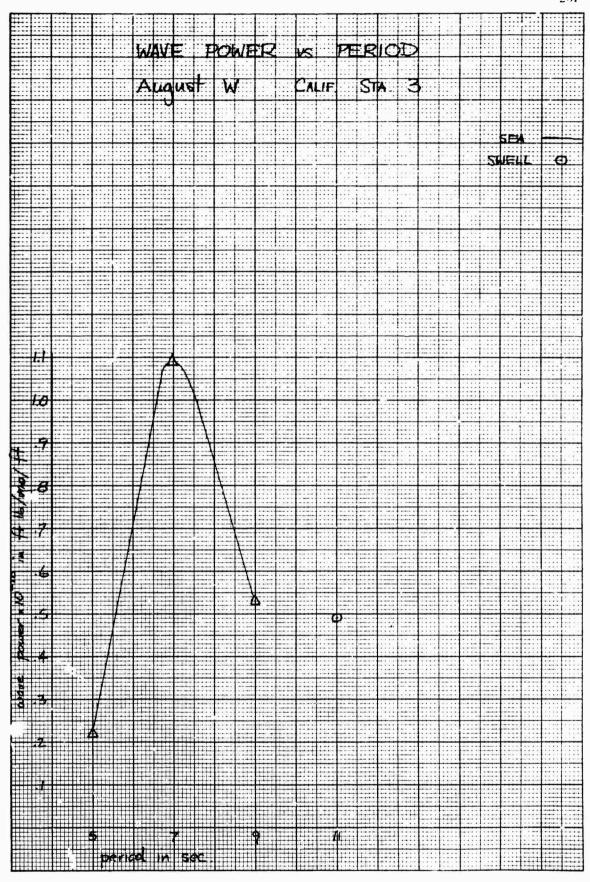
T X 10 INCHES HASEIN U.S.A. KEUFFEL & ESSER CO.

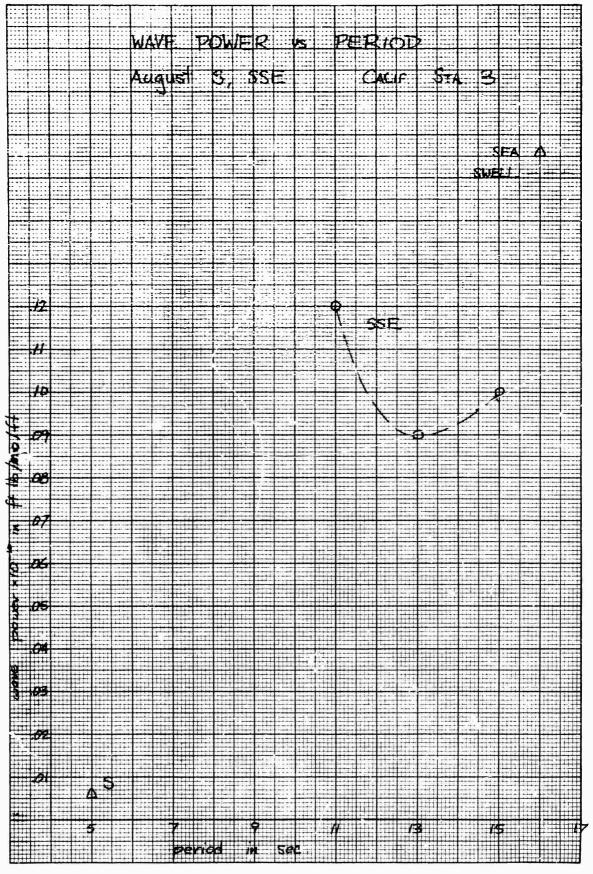


1 WAVE POWER PERIOD VS WNW August CALIF. STA 3 SEA ## /ow/ ## 7 9 period in sec **...**| :13:

KT 7 X 10 INCHES HASTRUSA . RECIPILISA . REUFFEL & SSER CO.

K-M 10 X 10 TO 1/2 INCH 46 1328
X X 10 INCHES
REUFFEL & ESSER CO.

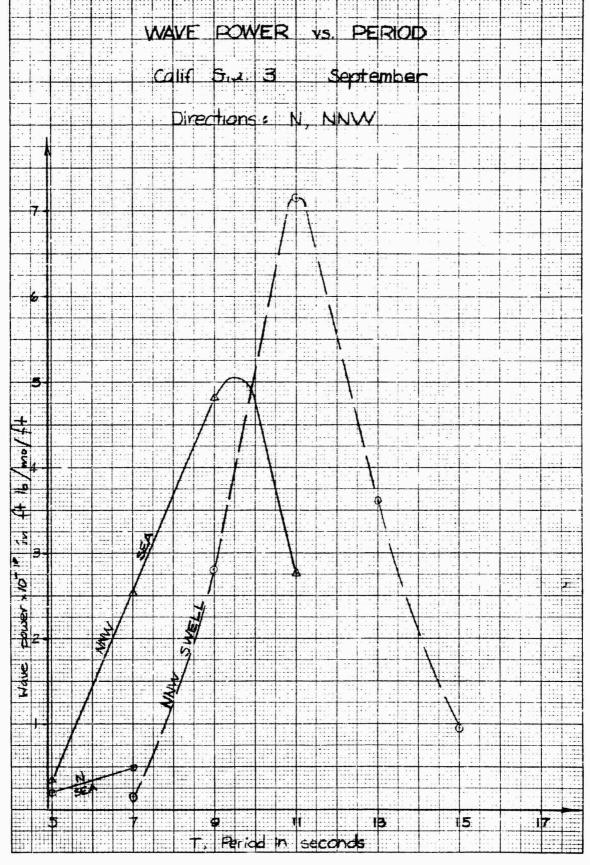




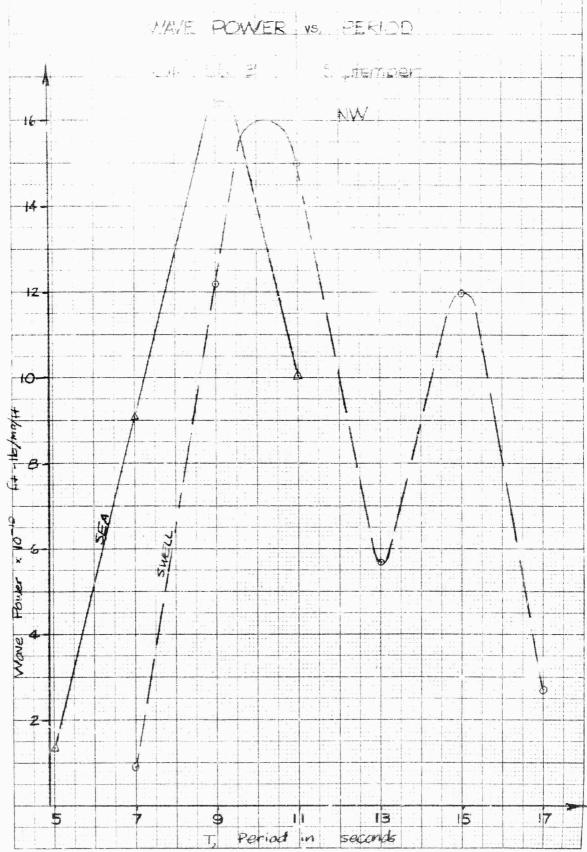
STATION 3 - SEPTEMBER

.... YS DIRECTION YVAVE POWER LAL SIA SEPTEMBER 5EA SWEL . |----| 1.... .1:::: ¥ 30 Power, KOE 10 X 10 TO 12 INCH 46 1323 X 10 INCHES AND IN U.S.A. KEUFIEL & ESSER CO. 75.42/ || || || || 10 IH. WSW . SSW 5 **3**55 M NNW NW WHYV W SW

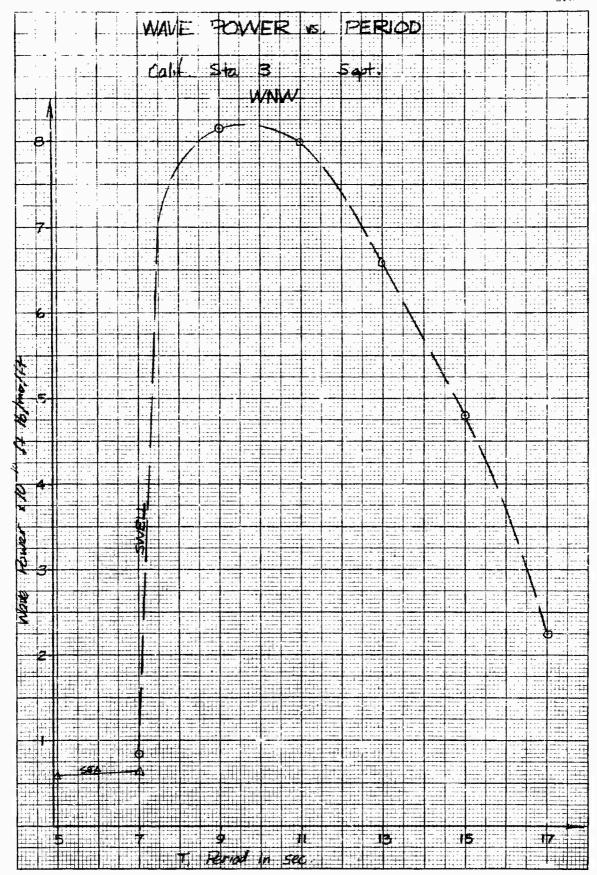
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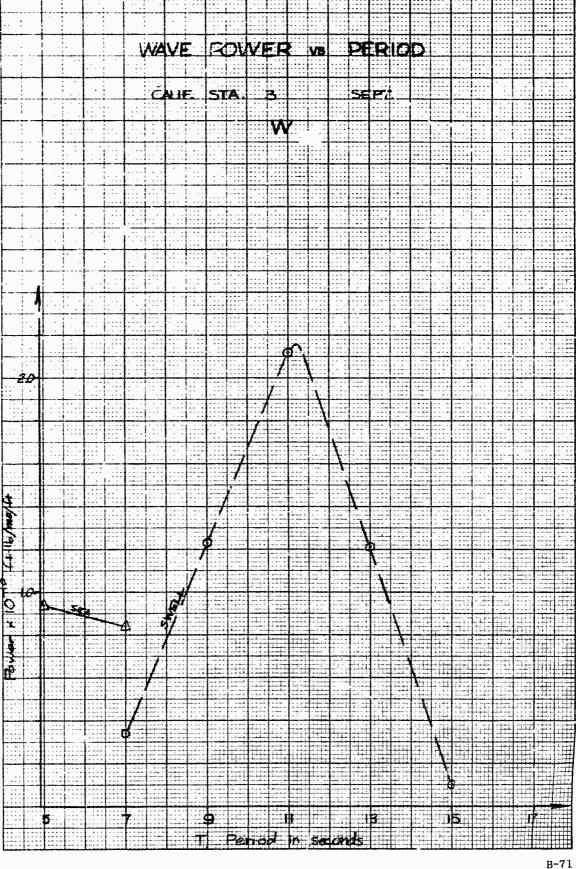
KON 10 X 10 TO 12 INCH 46 1323



B-69



B-70

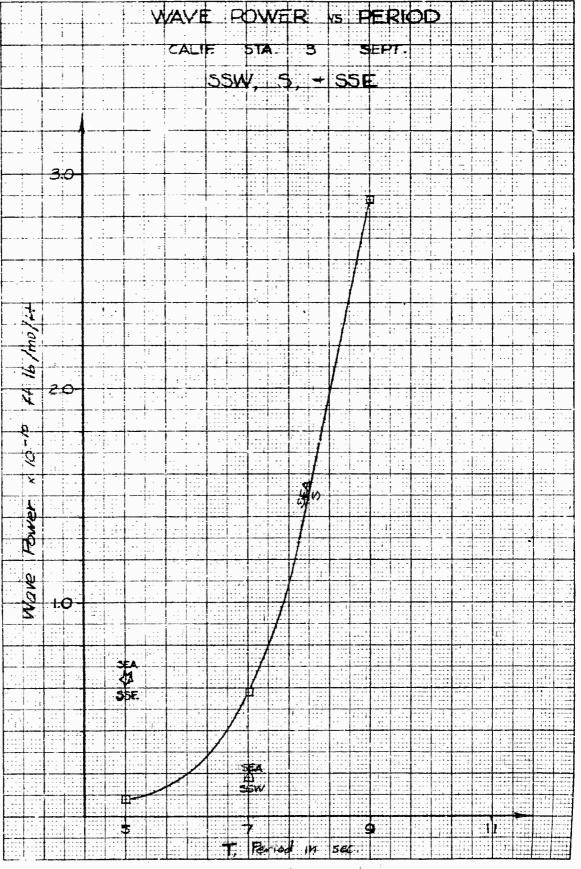


KOE 13 X 10 TO 12 INCH 46 1323

# 10 X 10 TO 72 INCH 46 1323
T X 10 INCHES
KEUFFEL & ESSER CC. a X. 6 五 2400

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POWER PERIOD .::I:: STA. W5W → 5W 1. :::: r i . . . . . : : : : ---: .... ::: .... ..... 11:11 ... ::::: ::: ·· 1.2 1 : :[. : 1 : ij... -:1: Ţ-. :-: ----11 .2 1 it Revide 5*8*C

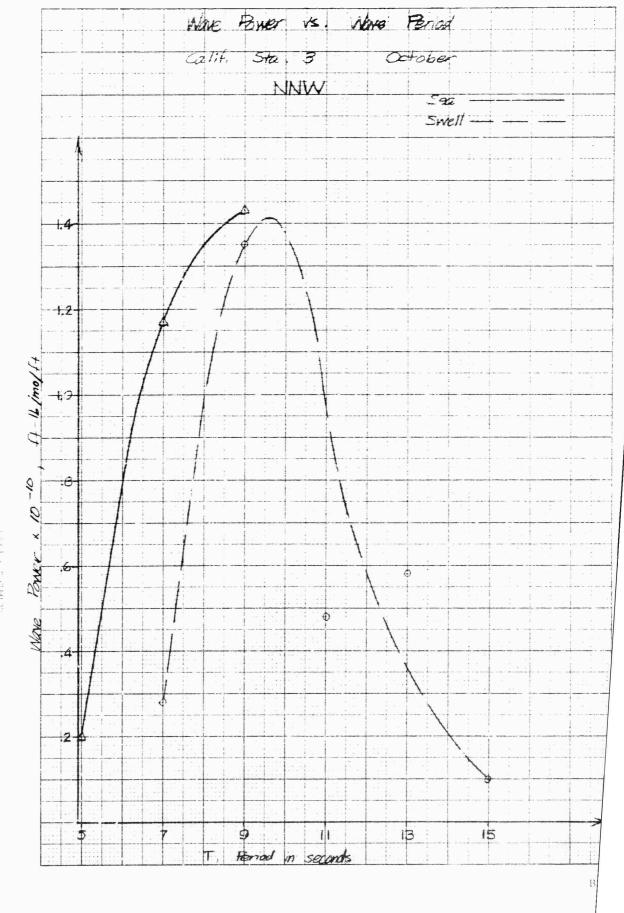


A TO X TO TO 12 INCH 46 1323

STATION 3 - OCTOBER

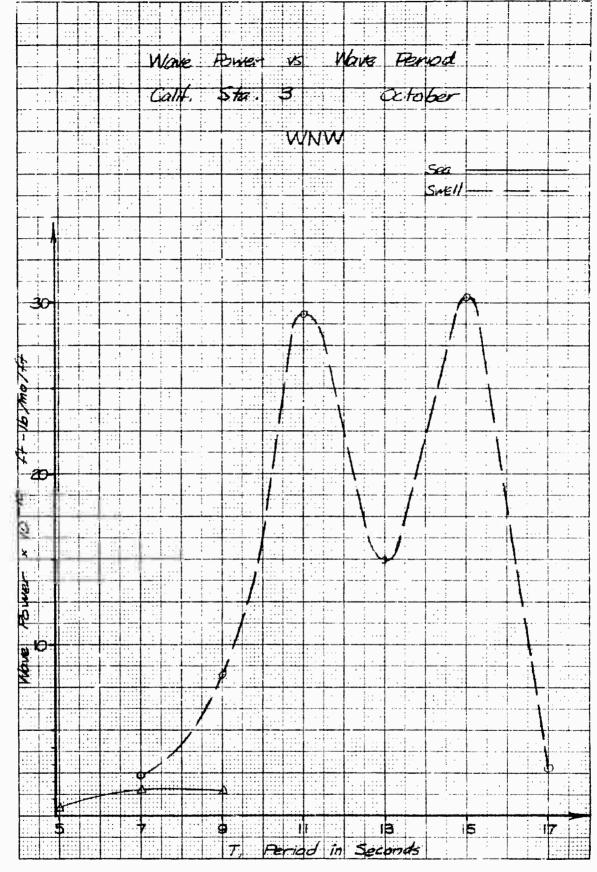
actober STA SWELL 13¢ 120 110 1070 96 L<sup>Q</sup> 70 : 6<del>0</del> S WSW SW SSW SSE NNW ΝW WNW 3-74

Kom 10 x 10 TO Va INCH 466 1323 AND X X 10 INChes MAREN U.B.A. INCHES A 688 EN CO.



Power 5h, 3 Calif October ----Sea. Swell : .; ++ (au/a) ++ をする 111 iri):: II. 13 • Period second's

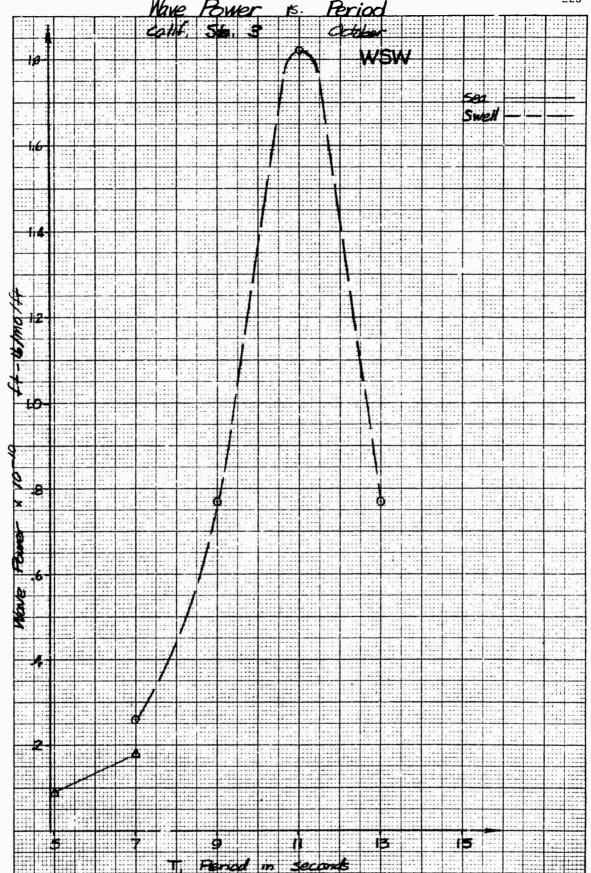
MOE 10 X 10 TO 12 INCH 46 1323

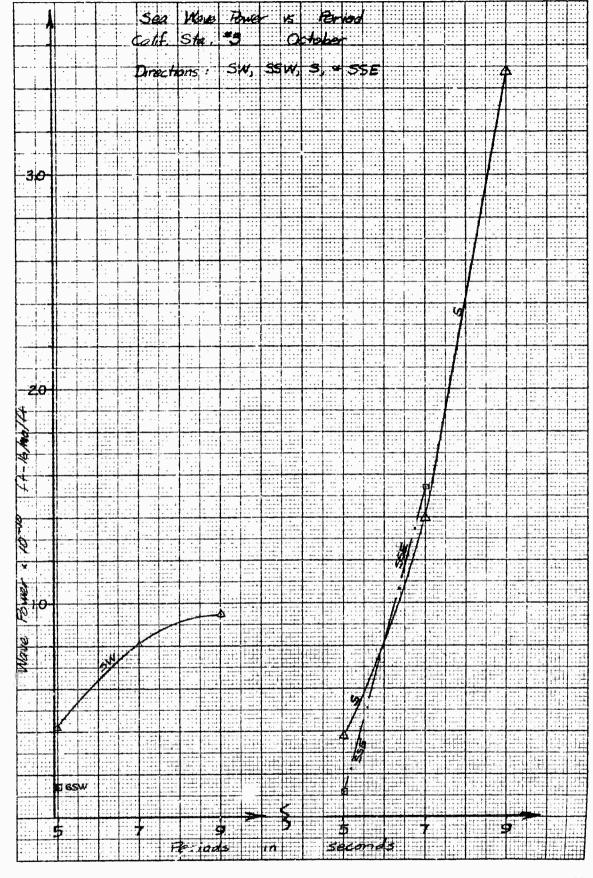


10 X 10 TO TO 12 INCH 46 1323

::∤:: Wave Power Forad 512. Colif October Sen FF-4,40 faret x 6 DOM 9 13 15 Period 7

KOZ 10 X 10 TO 12 INCH 46 1323 KEUFFEL & ESSER CO.



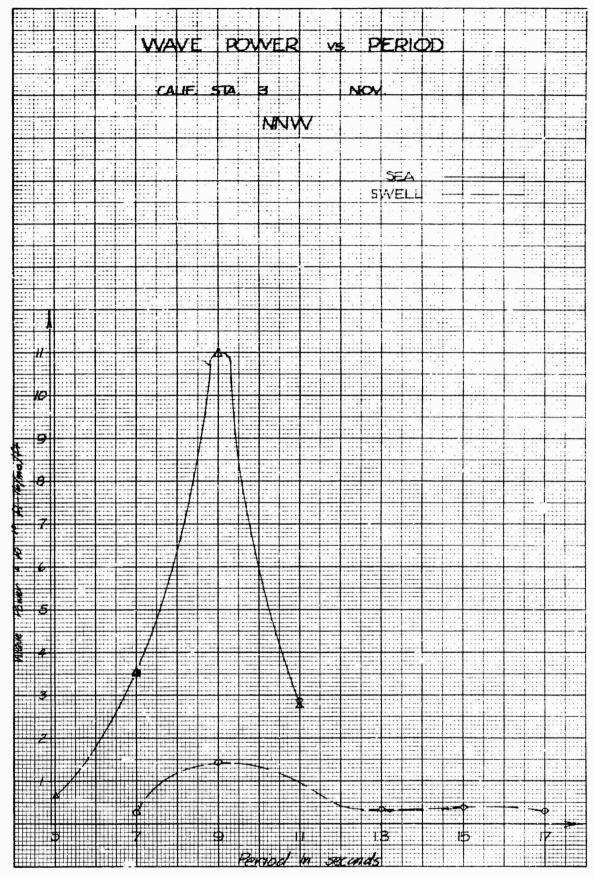


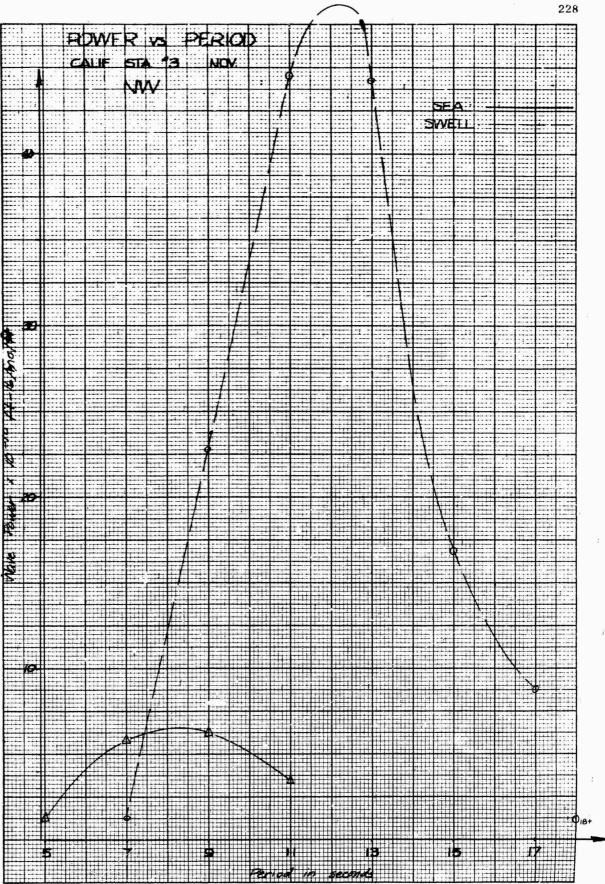
STATION 3 - NOVEMBER

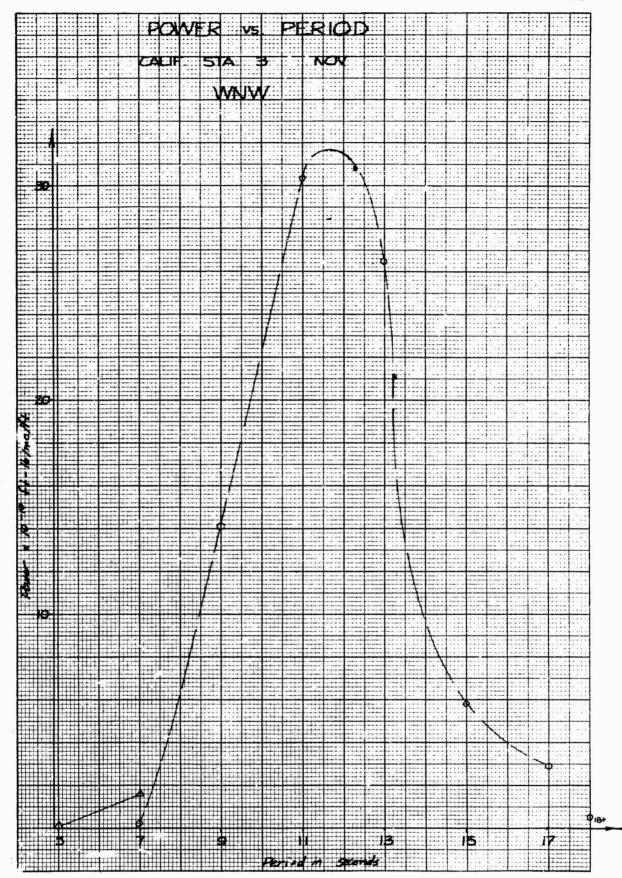
POVER VS. DIRECTION CALIF STA. 3 NOVEMBER 1.1 : . **SWELL** : : i · £0 -14/00mth/F4 ::: 1: Do-101 120 × Buer 00 Nove 80 Total 60 WSW SW SSW ธ SSE NNW NW WNW W B-81

KOE 10 X 10 TO 17 INCH 46 1923
KEUPIEL & ESSENCO

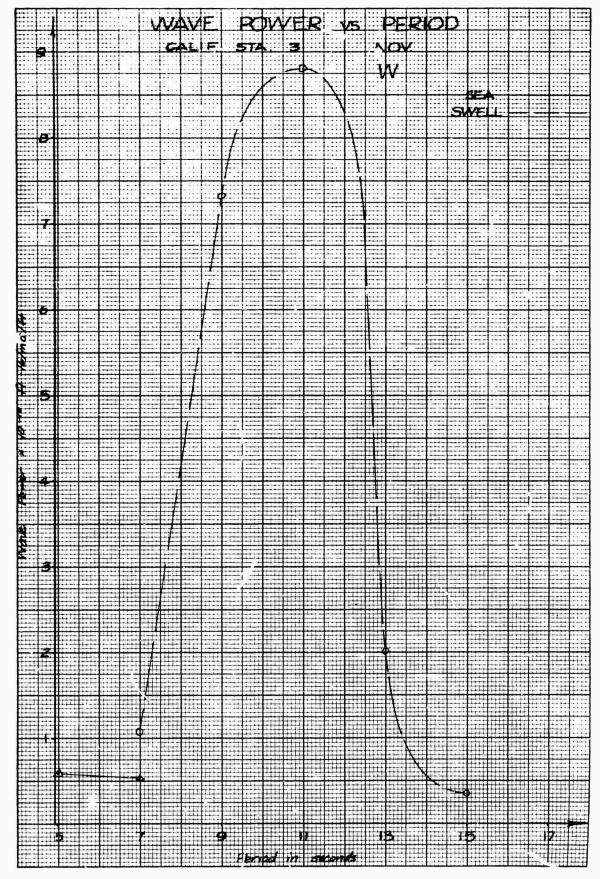








X-M 10 X 10 TO 1/2 INCH 46 1323 X X 10 INCHES MASER U.S.A . REUFFEL & RESER CO.



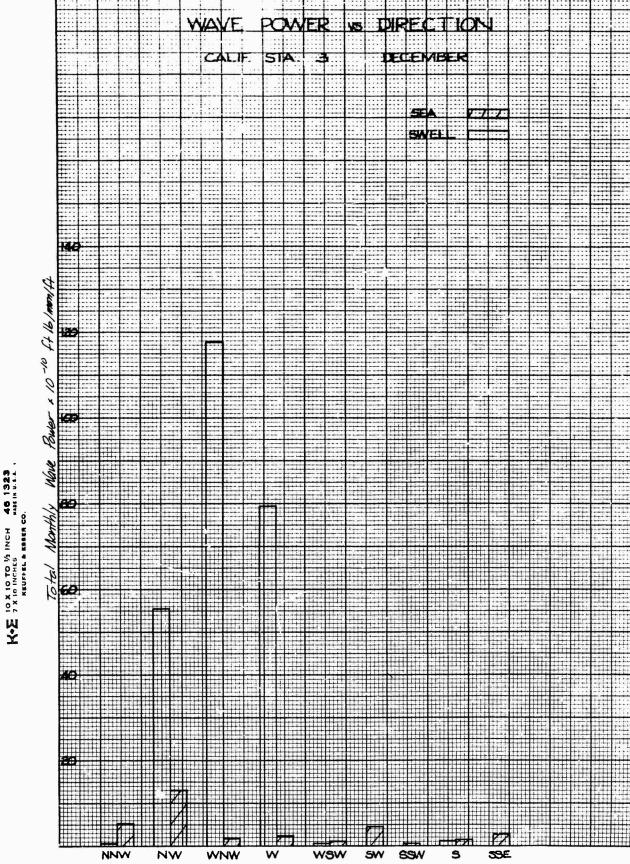
POWER VS PERIOD WAVE • : CALIF STA NOV. W5W : . . . . 1 :: 1: -: : : : ..... . .8 -----...imar : . 4 .... .... 11 7 10/ ¥... Burer - :-:: 1... . : 11 9 由 15 Ported 177 seconda

| A TO X 10 TO V2 INCH 46 1323

POWER PERIOD VS STA. NOVEMBE

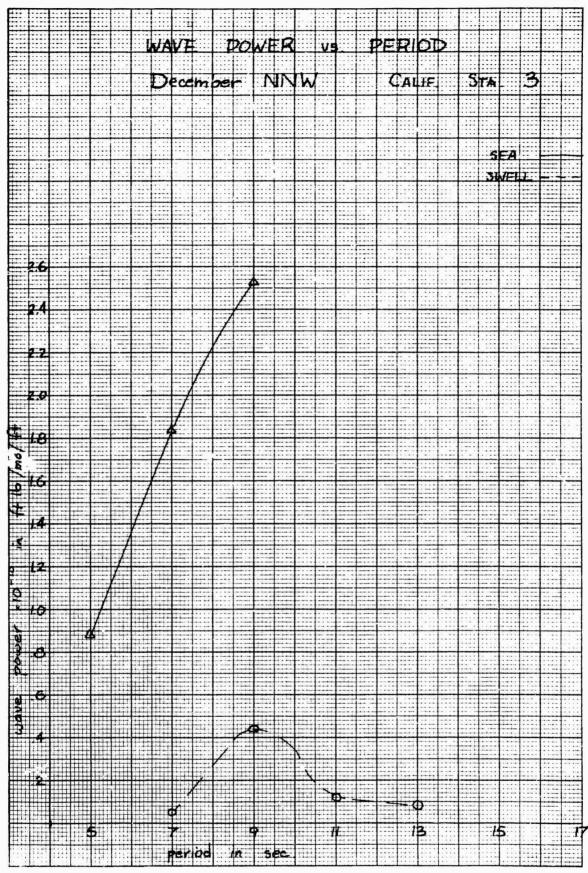
KOT 10 X 10 TO VA INCH 46 1323
KEUFPAL & ESSER CO.

STATION 3 - DECEMBER



B-88

KOZ 10 X 10 TO W INCH 46 1323 KEUPPEL & ESSEN CO.



POWER PERIOD 18 SEA 17 SHELL -/3 12 H 9 B-90

K-E 10 X 10 TO V2 INCH 46 1323

KEUTPEL RESER CO.

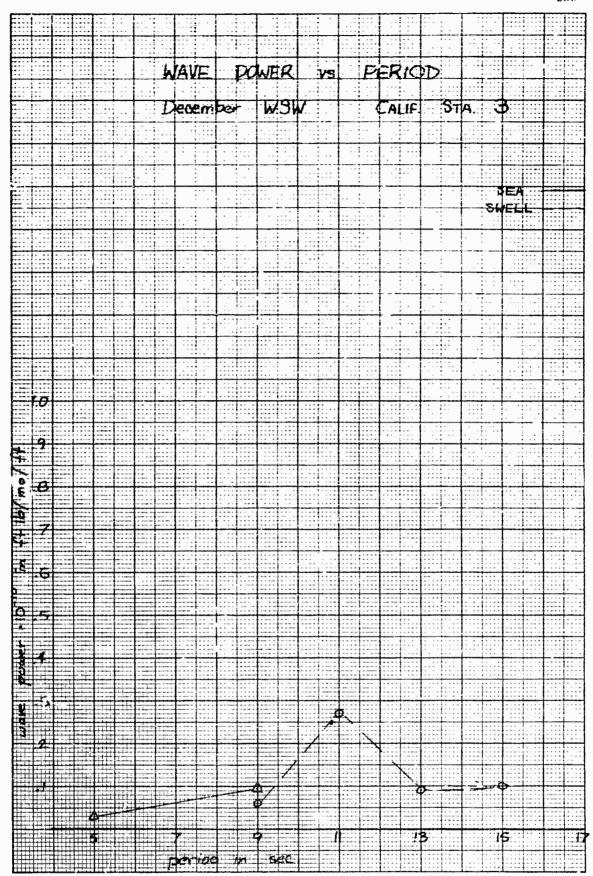
POWER WAVE PERIOL V9. CALIE 3 40 SWE. 35 30 1 1 0 A Mode # 10 # # # # \$ 7 9 W 18 period in sec

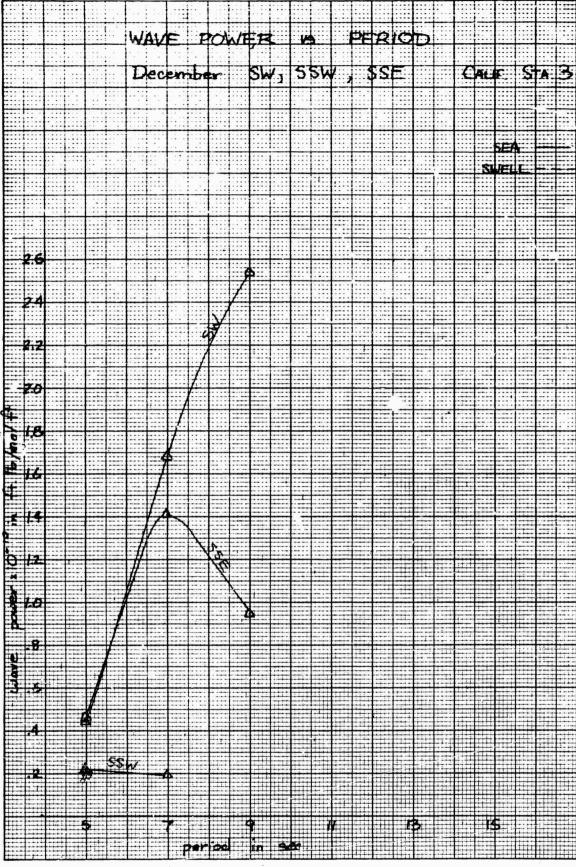
KOE 10 X 10 TO 12 INCH 46 1323
KOPPEL 8 SEER CO.

WAVE POWER PERIOD VS W. STA. 3 December CALIF. : -: ---.... - ;. -- :::: . . . . 35 30 4 <u>g</u> 0 15 10 净 13 sec

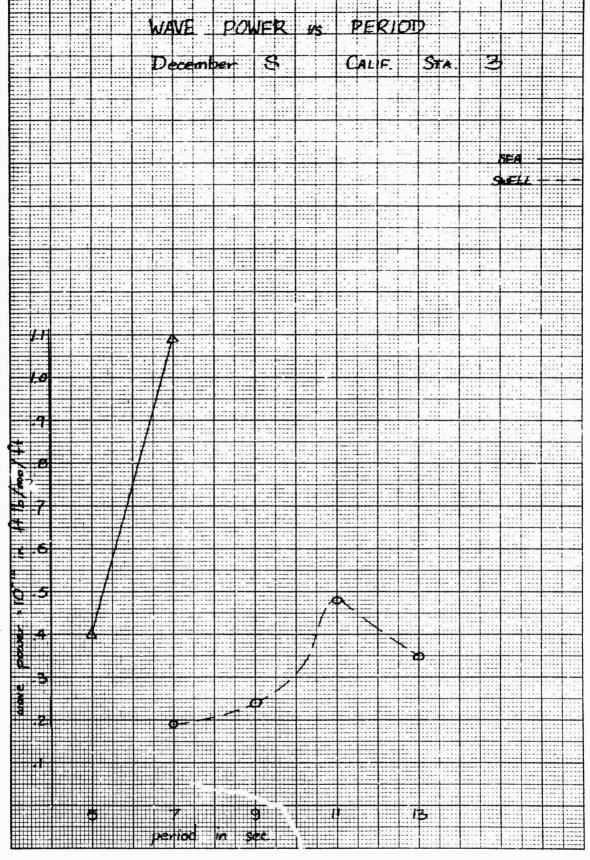
K-M 10 X 10 TO 12 INCH 46 1328
KEUPING BESSER CO

KOE 10 X 10 TO M INCH 46 1323 XX 10 INCHES XXII U.S. .





KT 1 X 10 X 10 TO V INCH 46 1323 KEUPPEL & ESSEN CO.



TX TO TO WHICH 46 1328
TX TO INCHES HARTHULLA .
KEUPPEL & KESKA CO.